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L A N D S A T   Data Continuity Mission
LDCM

LANDSAT DATA CONTINUITY MISSION

INSTRUMENT

MISSION ASSURANCE REQUIREMENTS

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Goddard Space Flight Center
Greenbelt, Maryland

National Aeronautics and Space Administration

CM FOREWORD

This document is a Landsat Data Continuity Mission (LDCM) Project Configuration Management (CM)-controlled document. Changes to this document require prior approval of the applicable Configuration Control Board (CCB) Chairperson or designee. Proposed changes shall be submitted to the LDCM CM Office (CMO), along with supportive material justifying the proposed change. Changes to this document will be made by complete revision.

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1.0 OVERALL MISSION ASSURANCE REQUIREMENTS

1.1 DESCRIPTION OF OVERALL REQUIREMENTS

The Systems Safety and Mission Assurance Program is applicable to LDCM instrument(s), (i.e., the Operational Land Imager (OLI) and the Thermal Infrared Sensor (TIRS)) and their associated developers. References made herein to the instrument Statement of Work (SOW) and Contract Data Requirements List (CDRL) refer respectively to the OLI and TIRS SOW and CDRL.

The developer is required to plan and implement an organized Systems Safety and Mission Assurance Program that encompasses:

- All flight hardware, either designed/built/provided by the developer or furnished by the GSFC, from project initiation through launch and mission operations.
- The ground system (e.g. test equipment, simulators, etc.) that interfaces with flight equipment to the extent necessary to assure the integrity and safety of flight items.
- All software critical for mission success.

Managers of the assurance activities shall have direct access to developer management independent of project management, with the functional freedom and authority to interact with all other elements of the project. Issues requiring project management attention shall be addressed with the developer(s) through the Project Manager(s) and/or Contracting Officer Technical Representative(s) (COTR).

1.2 SURVEILLANCE OF THE DEVELOPER

The work activities, operations, and documentation performed by the developer and/or his suppliers are subject to evaluation, review, audit, and inspection by government-designated representatives from GSFC, the Government Inspection Agency (GIA), or an independent assurance contractor (IAC). GSFC will delegate in-plant responsibilities and authority via a letter of delegation, or the GSFC contract with the IAC.

The developer and/or suppliers shall grant access for NASA and/or NASA representatives to conduct an assessment/survey upon notice. NASA will work with the developer to coordinate assessment activities at supplier facilities. Resources shall be provided to assist with the assessment/survey with minimal disruption to work activities. The developer, upon request, shall provide government assurance representatives with documents, records, and equipment required to perform their assurance and safety activities. The developer shall also provide the government assurance representative(s) with an acceptable work area within developer facilities as defined in the Statement of Work.

1.3 CONTRACT DELIVERY REQUIREMENTS LIST

The instrument Contract Delivery Requirements List (CDRL) identifies DRDs describing data deliverable to the GSFC Project Office. A complete list of CDRLs and associated DRDs may be found in the instrument CDRL.

2.0 QUALITY MANAGEMENT SYSTEM

2.1 GENERAL

The developer shall have a quality management system (QMS) that is compliant with the minimum requirements of American National Standards Institute (ANSI)/International Organization for Standardization (ISO)/American Society for Quality (ASQ) Q9001-2000. The developer's Quality Manual shall be provided in accordance with CDRL SA-1. The developer shall supplement their Q9001 Quality Manual with an LDCM instrument specific Systems Assurance Plan (CDRL SA-1) that defines on a chapter-by-chapter/section-by-section basis (referenced to the chapters of this document) how the developer will meet each requirement of this document. Every "shall" statement in this document is a requirement.

2.2 SUPPLEMENTAL QUALITY MANAGEMENT SYSTEM REQUIREMENTS

As mentioned previously, some assurance related activities are not covered by ISO requirements. These activities are identified in the following sections and should supplement the ANSI/ISO/ASQ Q9001 requirements.

2.2.1 Control of Nonconforming Product

The developer shall have a closed loop system for identifying and reporting nonconformances, ensuring that corrective action is implemented to prevent recurrence. The developer will audit and test as applicable to verify adequacy of the corrective action implemented. The system shall include a nonconformance review process, which shall consist of a preliminary review and a Material Review Board (MRB). The Government project Safety and Mission Assurance (SMA) representative shall sign off on all MRB activity relating to flight hardware or ground support equipment (GSE) that interfaces with flight hardware.

2.2.2 Preliminary Review

The preliminary review process shall be initiated with the identification and documentation of a nonconformance. A preliminary review shall be the initial step performed by developer-appointed personnel to determine if the nonconformance is minor and can readily be processed using the following disposition actions:

a. Scrapped, because the product is not usable for the intended purposes and cannot be economically reworked or repaired.

b. Re-worked, to result in a characteristic that completely conforms to the standards or drawing requirements.

c. Returned to supplier, for rework, repair or replacement.

d. Repaired using a standard repair process previously approved by the MRB and /or government Quality Assurance (QA) organization.

e. Referred to MRB when the above actions do not apply to the nonconformance.

Note: Preliminary review does not negate the requirement to identify, segregate, document, and report and disposition nonconformances.

2.2.3 Material Review Board

Nonconformances not dispositioned by preliminary review, normally critical and major nonconformances, shall be referred to the MRB for disposition. MRB dispositions shall include scrap, rework, return to supplier, repair by standard or non-standard repair procedures, use-as-is, or request for major waiver. The MRB shall consist of a core team including QA, supplemented with other disciplines brought in as necessary. It shall be chaired by a developer representative responsible for ensuring that MRB actions are performed in compliance with this standard and implemented per developer procedures.

The MRB shall consist of the appropriate functional and project representatives who are needed to ensure timely determination, implementation and close-out of recommended MRB disposition. The appropriate Safety and Mission Assurance personnel shall review all MRBs.

At developer/supplier facilities, NASA/Government representatives shall participate in MRB activities as deemed appropriate by Government management, otherwise, the MRB chairperson shall advise the Government of the MRB actions and recommendations. NASA will exercise the prerogative to review and approve all "use-as-is," standard and non-standard repair dispositions before they are initiated.

The MRB process shall investigate, in a timely manner, nonconforming item(s) in sufficient depth to determine proper disposition. For each reported nonconformance, there shall be an investigation and engineering analysis sufficient to determine cause and corrective actions for the nonconformance. Written authorization shall be provided to disposition the nonconformances.

2.2.4 Reporting of Failures

Reporting of failures will begin as early in the life cycle as possible. Reporting shall begin by the first acceptance testing of EEE parts, the first power application to any electronics assemblies, or with the first operation of a mechanical item. Software problem reporting shall begin with the first use of the flight build software. It shall continue through formal acceptance by the GSFC Project Office. Failures shall be reported in accordance with (CDRL SA-2).

Developer review/disposition/approval of failure reports shall be addressed by a Failure Review Board or Material Review Board as described in applicable procedure(s) included or referenced in the Quality Manual.

2.2.5 Control of Monitoring and Measuring Devices

Testing and calibration laboratories shall be compliant with the requirements of ISO 17025, "General Requirements for the Competence of Testing and Calibration Laboratories", or an LDCM Project approved equivalent.

2.2.6 New On-Orbit Design

The developer shall ensure modification of on-orbit flight software shall be in accordance with original system design specifications and validation processes.

2.2.7 Flow-Down

The developer's QA, reliability, and safety programs shall ensure flow-down of requirements to all suppliers, including a process to verify compliance. Specifically, contract review and purchasing processes shall indicate the processes for documenting, communicating, and reviewing requirements with sub-tier suppliers to ensure requirements are met.

Examples include, but are not limited to the following: Technical, Safety, Parts and Materials, Reliability, Quality Assurance, NASA Advisories, Government Industry Data Exchange Program (GIDEP) (Alerts, Safe-Alerts, Problem Advisories, and Agency Action Notices).

3.0 SYSTEM SAFETY REQUIREMENTS

3.1 GENERAL REQUIREMENTS

The system safety program shall be implemented by instrument developers for flight hardware, GSE, associated software, and support facilities. The system safety program shall be initiated in the concept phase of design and continue throughout all phases of the mission. GSFC shall certify safety compliance in support of the Pre-Shipment Review (PSR), and again at the Mission Readiness Review (MRR). The system safety program shall accomplish the following:

a. Provide for the early identification and control of hazards to personnel, facilities, support equipment, and the flight system during all stages of project development including design, development, fabrication, test, handling, storage, transportation, and pre-launch activities. The program shall address hazards in the flight hardware, associated software, GSE, operations, and support facilities, and shall conform to the safety review process requirements of NASA-STD-8719.8, "Expendable Launch Vehicle Payloads Safety Review Process Standard."

b. Meets the system safety requirements of AFSCM 91-710, "Range User Requirements Manual."

c. Meets the baseline industrial safety requirements of the institution, AFSPC 91-710 applicable Industry Standards to the extent practical to meet NASA and Office of Safety and Health Administration (OSHA) design and operational needs, and any special contractually imposed mission unique obligations. This should be documented in the contractor's Facility Health and Safety Plan.

Specific safety requirements include the following:

- If a system failure may lead to a catastrophic hazard, the system shall have three inhibits (dual fault tolerant). A <u>catastrophic hazard</u> is defined as: 1) A hazard that could result in a mishap causing fatal injury to personnel, and/or loss of one or more major elements of the flight vehicle or ground facility. 2) A condition that may cause death or permanently disabling injury, major system or facility destruction on the ground, or vehicle during the mission.

- If a system failure may lead to a critical hazard, the system shall have two inhibits (single fault tolerant). A <u>critical hazard</u> is defined as: a condition that may cause severe injury or occupational illness, or major property damage to facilities, system, or flight hardware.

- Hazards which cannot be controlled by failure tolerance (e.g., structures, pressure vessels, etc.) are called "Design for Minimum Risk" areas of design, and have separate detailed safety requirements that they must meet. Hazard controls related to these areas are extremely critical and warrant careful attention to the details of verification of compliance on the part of the developer.

3.2 SYSTEM SAFETY DELIVERABLES

3.2.1 System Safety Program Plan

The developer shall prepare a System Safety Program Plan (SSPP) (see CDRL SA-3) which describes in detail, tasks and activities of system safety management and system safety engineering required to identify, evaluate, eliminate and control hazards or reduce the associated risk to a level acceptable throughout the system life cycle.

The approved plan provides a formal basis of understanding between the instrument provider and GSFC Code 302 on how the System Safety Program will be conducted to meet the range safety requirements and spacecraft Integrator safety requirements, including general and specific provisions. The approved plan shall account for all contractually required tasks and responsibilities on an item-by-item basis, and will address the roles and responsibilities of each organization. The SSPP shall specify the hazard analyses required to be performed on flight hardware, GSE, integration and test (I&T) and pre-launch operations.

3.2.2 Safety Requirements Compliance Checklist

The developer shall demonstrate that the payload is in compliance with all safety requirements (or that Problem Failure Reports [PFRs]/waivers have been submitted and approved by GSFC Code 302 and the launch site safety representative). The developer shall document this in the Safety Requirements Compliance Checklist (see CDRL SA-6). Safety compliance shall be granted via GSFC Code 302 Safety Certification Letter to the Project Manager only after verification that all applicable safety requirements have been met.

3.2.3 Safety Analysis

The analyses described in the following sections are typical hazard analysis techniques. The following analyses shall be performed.

3.2.3.1 Preliminary Hazard Analysis

The purpose of this task is to perform and document a Preliminary Hazard Analysis (PHA) to identify safety critical areas, to provide an initial assessment of hazards, and to identify requisite hazard controls and follow-on actions.

The developer shall perform and document a PHA in accordance with (CDRL SA-4) to obtain an initial risk assessment of a concept or system. Based on the best available data, including mishap data from similar systems and other lessons learned, hazards associated with the proposed design or function shall be evaluated for hazard severity, hazard probability, and operational constraint. Safety provisions and alternatives needed to eliminate hazards or reduce their associated risk to a level acceptable to Range Safety shall be included.

3.2.3.2 Operations Hazards Analyses

The developer shall prepare an Operations Hazard Analysis (OHA) which describes the hardware and test equipment operations. The OHA shall be prepared in accordance with (CDRL SA-5), demonstrate that the planned I&T activities are compatible with the facility safety requirements, and that any inherent hazards associated with those activities is mitigated to an acceptable level. GSFC Code 302 is responsible for reviewing and approving the OHA. GSFC Code 302 shall also review all Work Order Authorizations (WOAs). Hazardous WOAs generated during I&T activities require GSFC Code 302 approval. All hazardous operations must be witnessed by GSFC Code 302.

During I&T activities, a Hazard Tracking Log (HTL) shall be used to track and close all remaining items. Closure methodology for the HTL is the same as for the VTL in section 3.4.

3.2.3.3 Software Safety

Hazards caused by software shall be identified as a part of the nominal hazard analysis process, and their controls shall be verified prior to acceptance. Hazard analysis recommendations typically require the software developer to demonstrate that adequate inhibits and/or controls are incorporated to eliminate or mitigate hazards to an acceptable level. Additional independent assessment may be required by the Government as dictated by the hazard probability and severity. Section 5.2.2 describes desired software safety activities to meet NASA HQ guidelines.

3.3 SAFETY ASSESSMENT REPORT

The instrument or subsystem developer shall perform and document a comprehensive evaluation of the mishap risk of their instrument or system. This report is used to assist the spacecraft developer/integrator in preparing the MSPSP for submittal to the launch range. This Safety Assessment Report (SAR) (refer to CDRL SA-8) shall identify all safety features of the hardware, software, and system design, as well as procedural related hazards present in the system.

It shall include:

a. Safety criteria and methodology used to classify and rank hazards.

b. Results of hazard analyses and tests used to identify hazards in the system.

c. Hazard reports documenting the results of the safety program efforts.

d. List of hazardous materials generated or used in the system.

e. Conclusion with a signed statement that all identified hazards have been eliminated or controlled to an acceptable level.

f. Recommendations applicable to hazards at the interface of their system.

All SAR deliveries shall be approved by the Government before submittal to the SC integrator.

3.4 VERIFICATION TRACKING LOG

The instrument developer shall establish a "closed loop" process for tracking all hazards to acceptable closure through the use of a Verification Tracking Log (VTL) (see CDRL SA-9). The VTL shall be delivered with the final SAR and updated regularly as requested until all items are closed. Individual VTL items shall be closed with appropriate documentation verifying the stated hazard control has been implemented, and individual closures shall be completed prior to the first operational use/restraint.

All open hazard control verification items shall be closed in accordance with applicable launch site range safety requirements before launch.

3.5 GROUND OPERATIONS PROCEDURES

The developer shall submit, in accordance with the contract schedule, all ground operations procedures (see CDRL SA-10) to be used at GSFC facilities, other integration facilities, or the launch site. All hazardous operations, as well as the procedures to control them, shall be identified and highlighted. All launch site procedures shall comply with the launch site and NASA safety regulations. GSFC Code 302 will review and approval all hazardous procedures before submittal to the launch range.

3.6 SAFETY VARIANCE

When a specific safety requirement cannot be met, the developer shall submit an associated safety variance, per NASA Procedural Requirement (NPR) 8715.3 and CDRL SA-11, which identifies the hazard and shows the rationale for approval of a variance. The following definitions apply to the safety variance approval policy:

a. Variance: Documented and approved permission to perform some act or operation contrary to established requirements.

b. Deviation: A documented variance that authorizes departure from a particular safety requirement that does not strictly apply or where the intent of the requirement is being met through alternate means that provide an equivalent level of safety with no additional risk. The OSHA requirements (1910 29 Code of Federal Regulations [CFR]) term for deviation is alternate or supplemental standard only when it applies to OSHA requirements.

c. Waiver: A variance that authorizes departure from a specific safety requirement where a special level of risk has been documented and accepted.

All requests for variance will be accompanied by documentation as to why the requirement cannot be met, what risks are involved, alternative means to reduce the hazard or risk, the duration of the variance, and comments from any affected employees or their representatives (if the variance affects personal safety).

3.7 SUPPORT FOR SAFETY MEETINGS

Technical support shall be provided to the Project for Safety Working Group (SWG) meetings, Technical Interface Meetings (TIMs), and technical reviews, as required. The SWG will meet as necessary to review procedures and analyses that contain or examine safety critical functions, or as convened by GSFC Code 302 to discuss any situations that may arise with respect to overall project safety. Meetings are normally held as a sidebar to other reviews and meetings, to minimize extra travel. There is no required number of meetings.

3.8 ORBITAL DEBRIS ASSESSMENT

The Instrument developer shall provide the necessary information, for use by the spacecraft developer and/or GSFC, for completion of the Orbital Debris Assessment in the Safety Assessment Report (CDRL SA-8). The spacecraft developer and/or GSFC will supply an Orbital Debris Assessment in accordance with NSS 1740.14, "Guidelines and Assessment Procedures for Limiting Orbital Debris" and NPR 8715.6, "NASA Procedural Requirements for Limiting Orbital Debris." Design and safety activities should take into account the observatory's ability to conform to debris generation requirements.

3.9 PRE-MISHAP PLAN DOCUMENT

The Instrument developer shall provide a Pre-Mishap Plan (CDRL SA-25) prior to initiating any project operations with potential for personnel injury or flight hardware damage. This includes any GSE loss or damage that could cause a flight delay or be of high value.

3.10 LAUNCH SITE SAFETY SUPPORT

The instrument developer shall provide and coordinate manpower requirements for safety support of all operations at the launch site. Range safety is not responsible for project safety support at the launch ranges. Safety support of hazardous I&T operations performed at the launch site needs to be planned and budgeted for by the project.

3.11 MISHAP REPORTING AND INVESTIGATION

All mishaps, incidents, hazards, and close calls shall be reported to on NASA Form NF1627 or equivalent form, per NPR 8621.1, "NASA Procedures and Guidelines for Mishap Reporting, Investigating, and Recordkeeping."

3.12 MISCELLANEOUS SUBMITTALS FOR RANGE USE

The Instrument developer shall provide information to the spacecraft integrator and GSFC as necessary to support generation of the following forms required by Range Safety.

- Material Selection List for Plastic Films, Foams, and Adhesive Tapes – (http://rtreport.ksc.nasa.gov/techreports/95report/msf/ms10.html). The list is published in GP-1098, KSC Ground Operations Safety Plan, Volume I, Safety Requirements, and is updated quarterly. Materials are evaluated for electrostatic discharge (ESD), flammability, and compatibility with hypergols. (Ship-60 day to GSFC)

- Radiation forms/analysis – KHB 1860.1 (KSC Ionizing Radiation Protection Program) and KHB 1860.2 (KSC Non-Ionizing Radiation Protection Program) includes forms for ionizing and non-ionizing radiation from Radio Frequency (RF), light, laser, and radioactive sources. Forms must be completed to provide information on the radiation source(s) and the source user(s). Procedures must also be submitted. (Ship-120 days to GSFC)

- Process Waste Questionnaire (PWQ) (Kennedy Space Center [KSC]/Eastern Range Only) – PWQ records all the hazardous materials that are brought to the range with the payload. Specific information on storage, containment, and spill control are required. (Ship- 60 days to KSC/Eastern Test Range [ETR])

4.0 RELIABILITY AND PROBABILISTIC RISK ASSESSMENT

4.1 GENERAL REQUIREMENTS

The developer shall implement a reliability program applicable to the development of all software and hardware products and processes.

4.1.1 Reliability Program Plan

The developer shall provide a Reliability Program Plan (CDRL SA-7) describing the planned approach and schedule for the project reliability activities, including the support and analyses they will provide to the developer of the mission level Probabilistic Risk Assessment (PRA). The developer shall identify in the plan the reliability tasks to be performed and how those tasks will be implemented and controlled. The developer shall discuss the scheduling of the reliability tasks relative to project milestones. The developer will ensure reliability functions are an integral part of the design and development process and the reliability functions interact effectively with other project disciplines, including systems engineering, hardware design, and product assurance. The developer shall describe how reliability assessments are integrated with the design process and other assurance practices, including operations planning; for example implementing workarounds to address credible failure conditions and degraded modes of operation. The developer shall describe the integration of reliability activities with the probabilistic risk assessment process. The developer shall ensure that system elements obtained from sub-developers and suppliers meet project reliability requirements, and shall ensure all subcontracts include provisions for review and evaluation of the sub-developers' and suppliers' reliability efforts by the prime developer at the prime developer's discretion, and by GSFC at its discretion. The plan shall be updated as required.

4.1.2 Probabilistic Risk Assessment

The developer shall support the development of a Limited Scope Probabilistic Risk Assessment (PRA) commensurate with a Class B mission as defined in NPR 8705.4, Risk Classification for NASA Payloads, and in accordance with the requirements of NPR 8705.5, Probabilistic Risk Assessment (PRA) Procedures for NASA Programs and Projects. The developer shall support the PRA development by providing instrument related analyses (PRA inputs) that are integral to the mission level PRA. A limited scope PRA is of the same general rigor as a full-scope PRA, but focuses on the mission-related end-states of specific decision-making interest, instead of all applicable end states.

Potential candidates for PRA analyses may come from mission operational working group meetings, reliability working group (RWG) meetings, safety hazard analyses, instrument and observatory FMEA, Instrument and Spacecraft Reliability Prediction Analyses, I&T Problem reports, etc. The instrument developer shall identify and use the appropriate types of analyses for each scenario modeled, and the modeling tools and techniques to be used (e.g., Master Logic Diagrams (MLD), Failure Mode and Effects Analysis (FMEA), Fault Tree Analyses (FTA), Event Tree Analyses (ETA), and/or Event Sequence Diagrams).

The developer shall use the PRA process to quantify risk and uncertainties associated with identifying pivotal events or scenarios that may cause a mission-ending failure or human safety hazardous condition. The developer shall support the implementation of the PRA procedures across every phase of the instrument life cycle.

The developer shall submit the PRA inputs (CDRL SA-13) to the project office for approval, and shall present a summary of the PRA inputs at all instrument design reviews, beginning with the Instrument Preliminary Design Review (IPDR). Presentations shall include design trade-study results and PRA results impacting design or risk decisions.

4.1.3 Design Reviews and Readiness Reviews

The developer's activities shall include support of internal and supplier design reviews at the system, subsystem, and component levels and NASA design and readiness reviews. This activity shall include an assurance function for compliance of the design to the design criteria defined for the instrument, subsystems and component levels.

4.1.4 Reliability Working Group Participation

The developer shall provide technical support to the Project for Reliability Working Group (RWG) meetings and technical reviews, as required.

The RWG will meet as necessary, and as convened by Government project personnel, to review reliability requirements and analyses, to assist in resolving reliability issues and concerns, and to discuss any situations that may arise with respect to overall mission reliability.

4.1.5 Reliability Progress Reporting

The developer shall report on the progress of the reliability effort through monthly status reports and periodic management meetings, beginning with PDR.

4.2 RELIABILITY ANALYSES

The developer shall ensure that reliability analyses are performed during the design phase so that identified problem areas can be addressed and any required corrective action can be taken in a timely manner. When hardware or software that was designed, fabricated, or flown on a previous project is considered to have demonstrated compliance with all of the governing requirements (including operating environment, duty cycles, power and interfaces), heritage reliability analyses may be deemed acceptable by the GSFC LDCM Reliability Engineer. The developer shall perform the following analyses for the instrument and shall support associated mission-level activities.

4.2.1 Failure Modes and Effects Analysis, Critical Items List, and Critical Items Control Plan

The developer shall perform a Failure Modes and Effects Analysis (FMEA) during the design phase to identify potential instrument failure modes during each phase of the mission, and the effect of those failures on related systems and the mission. As changes to the design are made, the developer shall revise the FMEA to reflect the current design. Failure modes shall, at a minimum, be assessed at the circuit card interface level (to include the first active components), assessing each potential failure mode for the effect at the level of analysis (circuit level), the next higher level, and the mission level. The FMEA shall be performed in accordance with CDRL SA-14. The developer shall use the results of the FMEA to evaluate the design against requirements. The developer shall ensure identified discrepancies are evaluated by management and design groups to determine the need for corrective action.

Severity categories shall be determined in accordance with Table 4-1:

Table 4-1. Severity Categories

Category	Severity Description
1	Catastrophic Failure modes that could result in serious injury, loss of life (flight or ground personnel), or loss of launch vehicle.
1R	Failure modes of identical or equivalent redundant hardware items that could result in Category 1 effects if all failed.
1S	Failure in a safety or hazard monitoring system that could cause the system to fail to detect a hazardous condition or fail to operate during such condition and lead to Category 1 consequences.
2	Critical Failure modes that could result in loss of one or more mission objectives as defined by the GSFC project office.
2R	Failure modes of identical or equivalent redundant hardware items that could result in Category 2 effects if all failed
3	Significant Failure modes that could cause degradation to mission objectives
4	Minor failure modes that could result in insignificant or no loss to mission objectives.

Failure modes resulting in severity categories 1, 1R, 1S or 2 shall be analyzed at a greater depth, to single parts if necessary, to identify the cause of failure.

A Critical Items List shall be developed from those failure modes that could result in serious injury, loss of life or loss of launch vehicle whether the result of credible single point failures (as defined in the Reliability Program Plan [CDRL SA-7]), or redundant failures, and shall include single point failures that could result in loss of one or more mission objectives. For each critical item, retention rationale shall be provided that describes justification for retaining the potential failure in the design. Retention rationale shall consist of design features, test, inspection, heritage and flight history, operational considerations, workarounds, etc., that reduce the likelihood of the failure occurring and reduce the potential consequences if the failure occurs.

The developer shall develop a Critical Items Control Plan (CDRL SA-15) which identifies the Critical Items List and the specific controls used to mitigate risks associated with each critical item. The Critical Items Control Plan shall require specific, traceable, and verifiable procedures be introduced into the design, manufacturing and test phases of the program to control and reduce the likelihood that critical items will fail on orbit. The Critical Items Control Plan shall also provide retention rationale for each critical item that describes justification for retaining the potential failure in the design.

Retention rationale shall consist of design features, test, inspection, heritage and flight history, operational considerations, workarounds, etc., that reduce the likelihood of the failure occurring and reduce the potential consequences if the failure occurs.

The developer shall present results of the FMEA and CIL at all design reviews, beginning with the Instrument Preliminary Design Review (IPDR). Presentations shall include design trade-study results and FMEA results impacting design or risk decisions.

4.2.2 Fault Tree Analysis

The developer shall prepare Fault Tree Analyses (FTAs), in accordance with CDRL SA-16, that address both mission failures and degraded modes of operation as pertains to the instrument. FTA's shall be performed and integrated as part of the PRA inputs. Component hardware/software failures, external hardware/software failures, and human factors shall be considered in the analysis.

The developer shall present results of the FTA at all design reviews, beginning with the Instrument Preliminary Design Review (IPDR). Presentations shall include design trade-study results and FTA results impacting design or risk decisions.

4.2.3 Parts Stress Analyses

The developer shall perform stress analyses on Electrical, Electronic, and Electromechanical (EEE) parts and devices, as applied in circuits within each component for conformance with EEE-INST-002. The analyses shall be performed in accordance with CDRL SA-22. The analyses shall be performed at the most stressful part-level parameter values that can result from the specified performance and environmental requirements on the assembly or component. The analyses shall be performed in close coordination with the packaging reviews and shall be required input data for component-level design reviews. The analyses shall be documented and maintained current to the latest design. The developer shall provide the analyses, summary sheets, and revisions to the Project Office for approval. Analyses results shall be presented at all design reviews beginning with PDR. Presentations shall include design trade-study results and Parts Stress Analyses results impacting design or risk decisions. Existing stress analyses that were not performed in accordance with EEE-INST-002 may be acceptable if approval is obtained from the GSFC Reliability Engineer.

4.2.4 Worst-Case Analyses

The developer shall perform worst-case analyses in accordance with CDRL SA-23 for mission or science-critical parameters that are subject to variations that could degrade instrument performance, where failure results in a severity category of 2 or higher, and provides data that question the flightworthiness of the design. Analyses or test or both shall demonstrate adequacy of margins in the design of electronic circuits, optics, electromechanical and mechanical items (mechanisms). The analyses shall consider all parameters set at worst-case limits due to manufacturing variability and worst-case environmental (including radiation) and aging stresses for the parameter or operation being evaluated. The analyses shall be updated in keeping with design changes. The developer shall provide the analyses, summary sheets, and revisions to the Project Office for approval. The analyses and updates shall be presented at all design reviews beginning with PDR. Presentations shall include design trade-study results and Worst Case Analysis results impacting design or risk decisions.

4.2.5 Numerical Assessments and Predictions

The developer shall perform comparative numerical assessments and/or reliability predictions in accordance with CDRL SA-26 to:

1. Assist in trade-studies by evaluating alternative design concepts, redundancy and cross strapping approaches, and part substitutions;
2. Identify the elements of the design which are potentially the greatest detractors of system reliability;
3. Identify those potential mission limiting elements and components that will require special attention in part selection, testing, environmental isolation, and/or special operations;
4. Evaluate the design in terms of mission success requirements
5. Evaluate the impact of proposed engineering changes and waiver requests on reliability.

The developer shall describe in their assessments the level of detail of a model suitable for performing the intended functions enumerated above. The results of the reliability assessments shall be reported at design reviews starting with IPDR. The presentations shall include comments on how the analyses were used to perform design trade-offs or how the results were taken into consideration when making design or risk management decisions.

4.2.6 Limited-Life Items Plan

The developer shall provide a plan to identify and manage limited life items. The developer shall submit the Limited-Life Items Plan in accordance with CDRL SA-24. In the plan, the developer shall define limited-life items, the impact on mission parameters, responsibilities for mitigating limited-life items, and provide a list of limited-life items, including data elements as follows:

- Expected life
- Required life
- Duty cycle
- Rationale for selection

The useful life period starts with fabrication and ends with completion of final orbital mission, including the disposal phase.

The developer shall list limited-life items including selected structures, thermal control surfaces, solar arrays and electromechanical mechanisms. The developer shall consider atomic oxygen, solar radiation, shelf-life, extreme temperatures, thermal cycling, wear and fatigue to identify limited-life thermal control surfaces and structure items; the developer shall include mechanisms such as seals, bearings, valves, actuators and scan devices when aging, wear, fatigue and lubricant degradation limit their life.

The developer shall maintain records allowing for evaluation of cumulative stress (time and cycles) for limited-life items, starting when useful life is initiated, and indicating the project activity that stresses the items.

The developer shall obtain a program waiver approval by GSFC when the use of an item whose expected life is less than its mission design life.

4.3 RELIABILITY ANALYSIS OF TEST DATA

The developer shall fully utilize test information during the normal test program to assess reliability performance and identify potential or existing problem areas.

4.3.1 Trend Analyses

The developer shall assess subsystems and components to determine measurable parameters that relate to performance stability and reliability. The developer shall monitor selected parameters for trends starting at component acceptance testing and continuing during the system integration and test phases. The developer shall ensure monitoring is accomplished within the normal test framework; i.e., during functional tests and environmental tests. The developer shall establish a system for recording and analyzing the parameters as well as any changes from the nominal (even if the levels are within specified limits). The developer shall maintain and submit a list of subsystem and components to be assessed, parameters to be monitored, and trend analysis reports in accordance with CDRL SE-3.

4.3.2 Analysis of Test Results

The developer shall analyze test information, trend data and failure investigations to evaluate reliability implications. The developer shall document identified problem areas, and ensure developer management takes corrective action. The developer shall include this information in progress reports to the Project, or in a separate monthly report. The developer shall report results of analyses at design reviews. The developer shall address in the report design trade studies and reliability prediction results impacting design or risk decisions.

4.4 CONTROL OF SUB-DEVELOPERS AND SUPPLIERS

The developer shall ensure that system elements obtained from sub-developers and suppliers meet project reliability requirements. All subcontracts shall include provisions for review and evaluation of the sub-developers' and suppliers' reliability efforts by the prime developer at the prime developer's discretion, and by GSFC at its discretion. The developer shall tailor the reliability requirements of this document in hardware and software subcontracts for the project. The developer shall exercise necessary surveillance to ensure that sub-developer and supplier reliability efforts meet overall system requirements.
The developer shall ensure the tailored requirements:

- Incorporate quantitative reliability requirements in subcontracted equipment specifications.
- Assure that sub-developers have reliability programs that are compatible with the overall program
- Review sub-developer assessments and analyses for accuracy and correctness of approach.
- Review sub-developer test plans, procedures and reports for correctness of approach and test details.
- Participate in sub-developer design reviews.
- Ensure that sub-developers, during the project operational phase, comply with the applicable system reliability requirements.

4.5 RELIABILITY OF GOVERNMENT FURNISHED EQUIPMENT

When the instrument includes components or other elements furnished by the Government, the developer shall be responsible for identifying and requesting from the Project Office adequate reliability data on the items. The developer shall use the reliability data provided by the Project Office to perform the reliability analyses. The developer shall formally notify the Project Office promptly when examination of the data or testing by the developer indicates that the reliability or maintainability of Government Furnished Equipment is inconsistent with the reliability requirements of the overall system

4.6 SOFTWARE RELIABILITY

Refer to Section 5.5 for software reliability requirements.

5.0 SOFTWARE ASSURANCE REQUIREMENTS

5.1 GENERAL

For the purposes of this section, all references to the developer shall include the prime software developer, as well as any subcontractors tasked in the development process.

5.2 SOFTWARE ASSURANCE

The developer's Software Assurance program shall address software assurance disciplines (i.e., Software Quality, Software Safety, Software Reliability, Verification and Validation, and Independent Verification and Validation) and functions for all flight and ground system software. The software assurance program shall apply to software and firmware developed under this contract, including Government off-the-shelf (GOTS) software, modified off-the-shelf (MOTS) software, and commercial off-the-shelf (COTS) software when included in a NASA system.

The developer shall identify a person responsible for directing and managing the Software Assurance Program (e.g., a software assurance manager). The developer shall document in the instrument Systems Assurance Plan (CDRL SA-1) how the Software Assurance Requirements will be met.

5.3 SOFTWARE QUALITY

The developer shall implement a Software Quality program to assure the quality of the software products and software processes. The function of software quality assurance assures that the standards, processes, and procedures correctly implemented and appropriate to the project. Software quality control assures adherence to those software requirements, plans, procedures and standards.

Product assurance activities shall be performed to assure:

- Standards and procedures for management, software engineering and software assurance activities are defined.
- All plans (e.g., Configuration Management [CM], Risk Management, Software Management Plan) required by the contract are documented and comply with contractual requirements.
- Standards, design, and code are evaluated for quality and issues.
- All software requirements are documented and traceable from instrument requirements to design, code and test (i.e., a software requirements traceability matrix).
- Software requirement verification status is updated and maintained via a software requirements verification matrix.

- Formal and acceptance-level software tests are witnessed to assure satisfactory completion and maintenance of test artifacts.

- Software products and related documentation (e.g., Version Description Documents [VDD] and User Guides) have the required content and satisfy their contractual requirements.

- Project documentation, including plans, procedures, reports, schedules and records are reviewed for impact to the quality of the product.

- Software quality metrics are captured, analyzed, and trended to ensure the quality and safety of the software products.

Process assurance activities shall be performed to assure:

- Management, software engineering, and assurance personnel adhere to specified standards and procedures and comply with contractual requirements.

- All plans (e.g., CM, Risk Management, and Software Management Plan) and procedures are implemented according to specified standards and procedures.

- Contract requirements are passed down to any subcontractors, and that the subcontractor's software products satisfy the prime developer's contractual requirements.

- Engineering peer reviews (e.g., design walkthroughs and code inspections) and software milestone reviews are conducted and action items are tracked to closure.

- A software problem reporting system and corrective action process is in place and provides the capability to document, search, and track software problems and anomalies.

- The software is tested to verify compliance with functional and performance requirements.

- Software safety processes and procedures are followed.

- Management, software engineering, and assurance personnel have received proper software assurance training.

5.4 SOFTWARE SAFETY

The developer shall ensure that safety considerations are integrated with the overall software assurance and systems safety program and is compliant with the software safety requirements of NASA-STD-8719.13, or with standards approved by the GSFC LDCM Project Office. The developer shall ensure that their approach to the software safety program is documented in the System Safety Program Plan as appropriate.

The developer shall ensure that software safety requirements are clearly identified, documented, tracked, and controlled throughout the lifecycle. The developer shall identify potential hazards and ensure implementation of safety critical requirements. The developer shall test all software safety critical components on ETU or flight simulator hardware to ensure that the safety requirements were sufficiently implemented and that applicable controls are in place to verify all safety conditions. The developer shall document in operational documentation all safety-related commands, data, input sequences and workarounds necessary for the safe operation of the system. The developer shall report on all software safety requirements, software safety issues and risks at all formal system-level reviews.

For software deemed software safety critical, the developer shall identify and document the software safety critical classification of each item in terms of criticality, severity, associated risks, and likelihood of occurrence. Software safety requirements shall also be clearly identified and distinguishable in the software requirements traceability matrix.

The developer shall continually monitor, assess, and review the software development efforts for changes that may affect the safety critical classification of the software and as necessary update engineering analyses to reflect these changes.

5.5 SOFTWARE RELIABILITY

The developer shall ensure that software reliability is incorporated into their software products. The software reliability program shall be tailored to the appropriate level based upon criticality of the software to the mission, software safety criticality, software complexity, size, cost, consequence of failure, and other attributes. The developer shall ensure that appropriate activities are planned to support the achievement and verification of the developer's software reliability requirements. Refer to IEEE Standard 982.1-1988, IEEE Standard Dictionary of Measures to Produce Reliable Software, for methods to evaluate software reliability.

5.6 VERIFICATION AND VALIDATION

The developer shall plan and implement a Verification and Validation (V&V) program in accordance with the SOW Paragraph 4.2.1.2.1.

5.7 INDEPENDENT VERIFICATION AND VALIDATION

The developer shall support NASA IV&V activities in accordance with the SOW paragraph 4.2.1.4.

5.8 GFE, EXISTING AND PURCHASED SOFTWARE

If the developer is provided software as government-furnished equipment (GFE), or will use existing or purchased software and firmware, the developer shall verify that the software and firmware meets the functional, performance, and interface requirements placed upon it. The developer shall ensure that the software and firmware meets applicable standards, including those for design, code, and documentation, or shall secure a LDCM Project waiver to those standards. Any significant modification to any piece of the existing software shall be subject to the provisions of the developer's quality management system and the provisions of this document. A significant modification is defined as the change of twenty percent of the lines of code in the software.

6.0 RISK MANAGEMENT REQUIREMENTS

Risk management requirements for LDCM instruments are specified in paragraph 1.7 in the instrument Statement of Work.

7.0 INTEGRATED INDEPENDENT REVIEW REQUIREMENTS

7.1 GENERAL REQUIREMENTS

The developer shall support a series of comprehensive system-level technical reviews that will be conducted by the GSFC Office of Systems Safety and Mission Assurance (OSSMA) Systems Review Office (SRO). These reviews cover all aspects of flight and ground hardware, software, and operations for which the developer has responsibility. In addition, the developer shall conduct a program of peer reviews at the component and subsystem level.

For each specified review conducted by the GSFC SRO, the developer shall:

a. Develop and organize material for oral presentation to the GSFC review team. Copies of the presentation material will be made available as specified in CDRL RE-6.

b. Support splinter meetings resulting from the review.

c. Produce timely written responses to recommendations and action items resulting from the review.

d. Summarize, as appropriate, the results of the engineering peer reviews conducted by the developer.

7.2 INSTRUMENT REVIEWS

Reviews required for LDCM instruments are specified in paragraph 1.2 in the instrument Statement of Work.

7.3 PEER REVIEWS

The Developer shall implement a program of peer reviews at the component and subsystem levels. In addition, packaging reviews shall be conducted on all electrical and electromechanical components in the flight system.

The packaging reviews shall specifically address the following:

a. Placement, mounting, and interconnection of EEE parts on circuit boards or substrates.

b. Structural support and thermal accommodation of the boards, substrates, and their interconnections in the component design.

c. Provisions for protection of the parts and ease of inspection.

The Developer peer reviews shall be conducted by personnel who are not directly responsible for design of the hardware under review. The GSFC Project Office and SRO shall be invited to attend the peer reviews, and shall be provided ten working days notification.

The peer reviews shall have RFA item recordation which are reviewed and assigned to appropriate personnel at the end of the reviews. The Developer team is required to submit written responses to recommendations and action items resulting from the reviews to GSFC in a timely manner.

The results of the reviews will be documented and the documents will be made available for review.

8.0 DESIGN VERIFICATION REQUIREMENTS

8.1 GENERAL

The developer shall conduct a Verification Program to ensure that the flight system meets the specified mission requirements. The program shall consist of functional demonstrations, analytical investigations, physical measurements and tests that simulate all expected environments.

The Design Verification Requirements are contained in the LDCM Environmental Verification Requirements (LEVR) Document and the instrument Statement of Work (SOW).

8.2 DOCUMENTATION REQUIREMENTS

The documentation requirements applicable to design verification are included in the instrument Statement of Work.

8.3 PERFORMANCE OPERATING TIME AND FAILURE-FREE PERFORMANCE TESTING

Performance operating time and failure-free performance testing shall meet the requirements specified in the LDCM Environmental Verification Requirements (LEVR) (GSFC 427-03-05) in section 2.3.4.

9.0 WORKMANSHIP STANDARDS

9.1 GENERAL

The developer shall plan and implement a Workmanship Program to assure that all electronic packaging technologies, processes, and workmanship activities selected and applied meet mission objectives for quality and reliability. See Section 13 for additional information on ESD control.

9.2 APPLICABLE DOCUMENTS

The current status and/or any application notes for the NASA standards can be can be found at http://workmanship.nasa.gov/. Standards published by IPC must be obtained from the IPC website http://www.ipc.org or for those with access to the NASA Technical Standards Program website, http://standards.nasa.gov/default.taf. The most current version of these standards shall be used for new procurements. However, if a specific revision is listed for a referenced standard, only that revision is approved for use, unless otherwise approved by project management.

Conformal Coating and Staking:

NASA-STD-8739.1 "Workmanship Standard for Staking and Conformal Coating of Printed Wiring Boards and Electronic Assemblies"

Soldering - Flight, Surface Mount Technology:

NASA-STD-8739.2 "Workmanship Standard for Surface Mount Technology"

Soldering - Flight, Manual (hand):

NASA-STD-8739.3 "Soldered Electrical Connections"

Soldering - Ground Systems:

IPC/ EIA J-STD-001 "Requirements for Soldered Electrical and Electronic Assemblies"

IPC/ EIA J-STD-001 "Space Addendum"

Crimping, Wiring, and Harnessing:

NASA-STD-8739.4 "Crimping, Interconnecting Cables, Harnesses, and Wiring"

Fiber Optics:

NASA-STD-8739.5 "Fiber Optic Terminations, Cable Assemblies, and Installation"

ESD Control:

ANSI/ESD S20.20 “Protection of Electrical and Electronic Parts, Assemblies and Equipment” (excluding electrically initiated explosive devices)

GSFC-WM-001 “Workmanship Manual for Electrostatic Discharge Control (excluding electrically initiated explosive devices)”

Printed Wiring Board (PWB) Design:

IPC-2221 “Generic Standard on Printed Board Design”

IPC-2222 “Sectional Design Standard for Rigid Organic Printed Boards”

IPC-2223 “Sectional Design Standard for Flexible Printed Boards”

PWB Manufacture:

IPC A-600 “Acceptability of Printed Boards”

IPC-6011 “Generic Performance Specification for Printed Boards”

IPC-6012B “Qualification and Performance Specification for Rigid Printed Boards”

IPC-6013 “Qualification and Performance Specification for Flexible Printed Boards”

IPC-6018 “Microwave End Product Board Inspection and Test”

9.3 DESIGN

9.3.1 Printed Wiring Boards

The printed wiring boards (PWB) manufacturing and acceptance requirements identified in this chapter are based on using PWBs designed in accordance with the PWB design standards referenced above. Space flight PWB designs shall not include features that prevent finished flexible and microwave boards from complying with the Class 3 requirements of the appropriate manufacturing standard (e.g., specified plating thickness, internal annular ring dimensions, etc.).

Design of rigid PWBs shall conform to the requirements of the Association Connecting Electronics Industries IPC-6012B Class 3/A product as defined by the 6012B Performance Specification Sheet for Space and Military Application. In the event of a conflict between the IPC design specifications, the 6012B Class 3 requirements, and the IPC Class 3/A requirements, the Class 3/A shall take precedence.

9.3.2 Assemblies

The design considerations listed in the NASA Workmanship and IPC standards listed above should be incorporated to the extent practical.

9.3.3 Ground Support Equipment that Interface with Space Flight Hardware

Any portion of Ground Support Equipment (GSE) that physically mate with flight hardware, that reside with space flight hardware in environments that simulate a space flight environment (e.g. connectors, test cables, etc.), or that interface directly with space flight hardware in any way, shall be designed and fabricated using space flight parts, materials and processes.

9.4 WORKMANSHIP REQUIREMENTS

9.4.1 Training and Certification

All personnel working on flight hardware shall be certified as having completed the required training appropriate to their involvement, as defined in the above standards or, when approved by project management, in the Developer's quality manual. This includes, but is not limited to, the aforementioned workmanship and ESD standards. At a minimum, certification shall include successful completion of formal training in the appropriate discipline. Recertification shall be in accordance with the requirements defined in the above workmanship standards.

9.4.2 Flight and Harsh Environment Ground Systems Workmanship

9.4.2.1 Printed Wiring Boards

Rigid PWBs shall be manufactured in accordance with Class 3/A requirements of the IPC 6012B; flexible and microwave boards shall be manufactured in accordance with Class 3 requirements of the above referenced IPC PWB manufacturing standards. In the event of a conflict, the requirements specified in the IPC 6012B for Class 3/A product shall take precedence over all other rigid board specifications. The Developer shall provide PWB test coupons to the GSFC Materials Engineering Branch (MEB) or a GSFC/MEB approved laboratory for evaluation. Coupon acceptance shall be obtained prior to population of flight PWBs. Test coupons and test reports are not required for delivery to GSFC/MEB if the Developer has the test coupons evaluated by a laboratory that has been approved by the GSFC/MEB, however, they shall be retained and included as part of the Project's documentation/data deliverables package.

9.4.2.2 Assemblies

Assemblies shall be fabricated using the appropriate workmanship standards listed above (i.e., NASA-STD-8739.3 for hand soldering; NASA-STD-8739.4 for crimping/cabling; NASA-STD-8739.5 for fiber optic termination and installation; NASA-STD-8739.2 for Surface Mount Soldering, etc.) and ANSI/ESD S20.20.

9.4.3 Ground Systems (Non-Flight) Workmanship

9.4.3.1 Printed Wiring Boards

Ground system PWBs not covered by Section 9.3.3 shall be manufactured in accordance with the Class 3 requirements in the above referenced IPC PWB manufacturing standards. For existing

GSE, where it is not possible to show compliance to Class 3 requirements, the developer shall obtain approval from the GSFC LDCM Project Office prior to use.

9.4.3.2 Assemblies

Assemblies shall be fabricated using the Class 3 requirements of J-STD-001 and ANSI/ESD S20.20. Critical assemblies shall be fabricated using the J-STD-001 Space Addendum. For existing GSE, where it is not possible to show compliance to Class 3 requirements, the developer shall obtain approval from the GSFC LDCM Project Office prior to use.

9.4.4 Documentation

The developer shall document the procedures and processes that will be used to implement the above referenced workmanship, design, and ESD control standards; including any procedures or process requirements referenced by those standards.

Alternate standards may be proposed by the developer. Proposals shall be accompanied by objective data documenting that mission safety or reliability will not be compromised. Their use is limited to the specific project and allowed only after they have been reviewed and approved by program management.

9.5 NEW AND ADVANCED MATERIALS AND PACKAGING TECHNOLOGIES

New and/or existing advanced materials and packaging technologies (e.g., multi-chip modules [MCMs], stacked memories, chip on board [COB], ball grid array [BGA], etc.) shall be reviewed and approved by the Government Parts Engineer for EEE parts or the Government Materials Assurance Engineer (MAE) for materials and processes.

9.6 HARDWARE HANDLING

The developer shall use proper safety, ESD control and cleanroom practices (where appropriate) when handling flight hardware. The electrostatic charge generation and contamination potential of materials, processes, and equipment (e.g., cleaning equipment, packaging materials, purging, tent enclosures, etc.) shall be addressed.

9.7 SPECIAL PROVISIONS

9.7.1 Precision Component Assembly

When precise location of a component is required, the design shall use a stable, positive location system (not relying on friction) as the primary means of attachment.

9.7.2 Capping of Test Points and Plugs

All test points and plugs shall be capped or protected from discharge for flight.

9.7.3 Electrical Connector Mating

Mating of all flight connectors which can not be verified via ground tests, shall be clearly labeled and keyed uniquely, and mating of them shall be verified visually to prevent incorrect mating.

9.7.4 Solder Joint Intermetallics Mitigation

All materials comprising solder joints shall be selected to avoid the formation of potentially destructive intermetallic compounds.

10.0 MATERIALS AND PROCESS REQUIREMENTS

10.1 GENERAL REQUIREMENTS

The developer shall develop and implement a Materials and Processes Control Plan (MPCP) (CDRL SA-20) to be implemented by the beginning of the hardware design stage. The MPCP shall be compliant with the specific requirements of this section and the relevant LDCM surveillance, documentation, safety and contamination control requirements specified in other sections of this MAR. The plan shall document developer's policies, procedures and guidelines for the selection, processing, inspection, testing, procurement and control of materials, and lubricants employed to meet the design and operational requirements of the LDCM instrument. The Government LDCM Materials Assurance Engineer (MAE) shall approve developer materials, lubrication usage, and associated manufacturing processes prior to their use in spaceflight hardware.

Existing developer in-house documentation may be used and referenced in the plan to address how these requirements are to be met, and shall be available to the Government for review and approval. All appropriate sub-developers shall participate in the MPCP to the extent required by the prime developer and the Government in order to meet these requirements. The plan shall address how the developer will ensure the flow down of applicable MPCP requirements to sub-developers.

At the request of the Government, the developer shall deliver hardware to the Government for direct or indirect examination. The Government intends to make these requests on a non-interference basis. Direct examinations may take the form of non-destructive evaluations such x-ray fluorescence for plating thickness verification, or sample destructive examinations such as total ionizing dose tests for microcircuits or printed wiring board cross section examinations. Indirect examination will be used when direct examination is not possible. Methods of indirect examinations may include inspection of similar hardware produced on the same production line by the same personnel as the flight hardware.

10.2 MATERIALS SELECTION REQUIREMENTS

To qualify as a material compliant with intended spaceflight use, a material shall have a satisfactory flight heritage, be approved by the Government and meet the following applicable selection criteria as defined herein for:

1. Vacuum outgassing
2. Stress corrosion cracking (SCC)
3. Lubrication requirements
4. Manufacturing process selection
5. Fastener integrity

Thorough evaluation of the environmental effects of the trajectory paths/orbits shall be assessed for the impact on materials selection and design. The selection and use of material with

hazardous properties (such as flammability and toxicity) shall meet the requirements specified in AFSCM 91-710 Range Safety User Requirements Manual, Chapters 10 and 12.
A material that has limited spaceflight heritage or does not meet the applicable selection requirements listed above shall be considered non-compliant. In that case, if there are no alternatives available to select a compliant material, the material's usage shall be justified for the desired application on the basis of test, similarity, analyses, inspection, existing data, or a combination of those data. Government approval shall be obtained by the developer prior to use. Materials used in structural applications shall be highly resistant to SCC as specified in MSFC-STD-3029. A Materials Usage Agreement (MUA) (Figure 10-1) and/or a Stress Corrosion Evaluation Form (Figure 10-2) shall be submitted to the LDCM for approval for use of the proposed non-compliant material. Both forms are required for a material that does not meet the SCC requirements. The developer may use their own forms if they contain equivalent information and justification.

<table>
<tr><td colspan="4">MATERIAL USAGE AGREEMENT</td><td colspan="5">USAGE AGREEMENT NO.:</td><td colspan="3">PAGE OF</td></tr>
<tr><td colspan="2">PROJECT:</td><td colspan="2">SUBSYSTEM:</td><td colspan="5">ORIGINATOR:</td><td colspan="3">ORGANIZATION:</td></tr>
<tr><td colspan="2">DETAIL DRAWING</td><td colspan="3">NOMENCLATURE</td><td colspan="3">USING ASSEMBLY</td><td colspan="4">NOMENCLATURE</td></tr>
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<tr><td colspan="6">MATERIAL & SPECIFICATION</td><td colspan="6">MANUFACTURER & TRADE NAME</td></tr>
<tr><td colspan="6"></td><td colspan="6"></td></tr>
<tr><td>USAGE</td><td colspan="2">THICKNESS</td><td>WEIGHT</td><td colspan="2">EXPOSED AREA</td><td colspan="6">ENVIRONMENT</td></tr>
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<tr><td colspan="12">APPLICATION:</td></tr>
<tr><td colspan="12">RATIONALE:</td></tr>
<tr><td colspan="5">ORIGINATOR:</td><td colspan="4">PROJECT MANAGER:</td><td colspan="3">DATE:</td></tr>
</table>

Figure 10-1. Material Usage Agreement

1. Part Number ____
2. Part Name ____
3. Next Assembly Number __________________________________
4. Manufacturer ____
5. Material ____
6. Heat Treatment ____
7. Size and Form ____
8. Sustained Tensile Stresses-Magnitude and Direction
   a. Process Residual ______________________________________
   b. Assembly ____
   c. Design, Static ____
9. Special Processing ______________________________________
10. Weldments
   a. Alloy Form, Temper of Parent Metal ___________________
   b. Filler Alloy, if none, indicate ______________________
   c. Welding Process _______________________________________
   d. Weld Bead Removed - Yes ( ), No ( ) ___________________
   e. Post-Weld Thermal Treatment ___________________________
   f. Post-Weld Stress Relief _______________________________
11. Environment ____
12. Protective Finish ______________________________________
13. Function of Part _______________________________________
14. Effect of Failure ______________________________________
15. Evaluation of Stress Corrosion Susceptibility ____________
16. Remarks: ____

Figure 10-2. Stress Corrosion Evaluation Form

The developer shall create and maintain an As-Designed/As-Built Materials and Processes (M&P) List of all materials planned for use in the configured flight hardware (CDRL SA-21). This list shall include a Polymeric Materials and Composites Usage List, an Inorganic Materials and Composites Usage List, a Lubrication Usage List, and a Materials Process Utilization List.

The initial As-Designed M&P List and subsequent updates shall be submitted for review and approval by the LDCM MAE. An As-Built M&P list shall also be prepared and submitted for review and approval by the LDCM MAE. The developer shall provide a final As-Built M&P list that includes all materials, processes, and lubrication being used in the as-built configured flight article designated to fly and as delivered with the LDCM instrument.

Each M&P list shall be an itemization of the materials, processes and lubricants used in the configured flight article and shall contain as a minimum the information in Figures 10-3 through 10-6, respectively.

In order to minimize materials and lubricant problems during use in space hardware, the developers shall anticipate and consider potential application problem areas during the material selection process. Potential problem areas and application factors to be considered include radiation effects, electrostatic discharging, thermal cycling, SCC, galvanic corrosion, hydrogen embrittlement, lubrication, contamination of cooled surfaces, composite materials, atomic oxygen , limited life, vacuum outgassing, toxicity, flammability and fracture toughness, as well as the properties required by each material usage or application.

10.2.1 Inorganic Materials

The developer shall prepare and document an Inorganic Materials and Composites List (Figure 10-3) or the developer's equivalent. The list shall be submitted as part of the M&P list (CDRL SA-21). In addition, the developer may be requested to submit supporting applications data. The criteria specified in MSFC-STD-3029 shall be used to determine that metallic materials meet the stress corrosion cracking (SCC) criteria. A MUA shall be submitted to the LDCM MAE for each material usage that does not comply with the MSFC-STD-3029 SCC requirements.

GSFC Spacecraft Inorganic Materials List

Spacecraft		System/Experiment	
Contractor		Contractor Address	
Prepared by		Phone and Fax #	
GSFC MAE		Date Prepared	
Date Rec'd		Project SAM	

Item No.	Material Identification	Condition	Application	Expected Environment	MSFC-STD-3029 Rating

Figure 10-3. Inorganic Materials and Composites List

The use of tin, zinc, and cadmium platings in any flight application requires an MUA prior to use of that material. Bright tin, cadmium, and zinc platings have the potential for developing whisker growths. For tin, these have been measured up to 12.5 microns in diameter and up to 10 millimeters (mm) in length. These whiskers can result in short circuits, plasma arcing, and debris generation within the spacecraft. Zinc and cadmium platings also evaporate in vacuum environments and may redeposit on optics or electronics, posing potential risks to flight hardware.

10.2.2 Vacuum Outgassing of Polymeric Materials

Only materials that have a total mass loss (TML) less than 1.00% and a collected volatile condensable mass (CVCM) less than 0.10% shall be approved for use in a vacuum environment. Material vacuum outgassing shall be determined in accordance with American Society for Testing of Materials (ASTM) E-595. If a material exceeds these maximum limits, the developers shall be required to either replace with a compliant material or bring it into compliance via a vacuum bakeout, and/or to submit a MUA for its usage. In general, a material is qualified on a product-by-product basis. However, lot testing may be required by the Government of any material for which lot variation is evident or suspected. In such cases, unless supporting justification is provided negating additional lot testing via an MUA, material approval is contingent upon lot testing.

The developer shall prepare and submit a Polymeric Materials and Composites Usage List as indicated in Figure 10-4, or the developer's equivalent, as part of the M&P list (CDRL SA-21).

GSFC Spacecraft Polymeric Materials List

Spacecraft		System/Experiment		Date Prepared	
Contractor		Contractor Address		Phone & Fax #	
Prepared by					
GSFC MAE					
Project SAM					
Date Rec'd					

Amount Code

Area, cm^2	Vol, cc	wt, gm
1. 0-1	A. 0-1	a. 0-1
2. 2-100	B. 2-50	b. 2-50
3. 101-1000	C. 51-500	c. 51-500
4. > 1000	D. > 500	d. > 500

Item No.	Component	Material Identification	Mix Formula	Cure Details	Amount Code	Expected Environment	ASTM-E-595	
							%TML	%CVCM

Figure 10-4. Polymeric Materials and Composites Usage List

10.2.3 Lubrication Systems

Lubricants shall be selected for use with materials on the basis of flight heritage and valid test results that confirm the suitability of the composition and the performance characteristics for each specific application, including compatibility with the anticipated environment and contamination concerns.

All lubricated mechanisms shall be life tested unless it can be established and documented that a valid flight heritage exists to an identical mechanism used in an identical flight application or to an identical mechanism that has been separately qualified by suitable life testing.

The developer shall prepare and submit a Lubrication Usage List as indicated in Figure 10-5, or the developer's equivalent, as part of the M&P list (CDRL SA-21). In addition, the developer may be required by the Government to submit supporting applications data.

GSFC Spacecraft Lubrication Materials List

Spacecraft		System/Experiment	
Contractor		Contractor Address	
Prepared by		Phone and Fax #	
GSFC MAE		Date Prepared	
Date Rec'd		Project SAM	

Wear Codes

Type		# Cycles	Speed
CUR	continuous unidirectional rotation	A $1\text{-}10^{2}$	rpm rev/min
CO	continuous oscillation	B $10^{2}\text{-}10^{4}$	opm osc/min
IR	intermittent rotation	C $10^{4}\text{-}10^{6}$	vs variable
IO	intermittent oscillation	D $>10^{6}$	cpm cm/min
SO	small oscillation (<30)		
LO	large oscillation (>30)		
CS	continuous sliding		

Item No.	Component Type, Size, and Material	Proposed Lubricant and Amount	Type and # of Wear Cycles	Speed, Temp, & Atm of Operation	Type of Loads and Amount

Figure 10-5. Lubrication Usage List

10.2.4 Process Selection Requirements

Manufacturing processes (e.g., conformal coating, adhesive bonding, lubrication, heat treatment, welding, chemical or metallic coatings, etc.) shall be carefully selected to preclude unacceptable material property changes during exposure to flight environments that could cause adverse effects to the material and/or to the intended applications.

The developer shall create and maintain a Materials Processes Utilization List with the format and content indicated in Figure 10-6, or the developer's equivalent, as part of the M&P list (CDRL SA-21).

GSFC Spacecraft Materials Processes List

Spacecraft		System/Experiment	
Contractor		Contractor Address	
Prepared by		Phone and Fax #	
GSFC MAE		Date Prepared	
Date Rec'd		Project SAM	

Item No.	Process Type	Contractor Spec #	MIL, ASTM or other Spec #	Description of Material Processed	Spacecraft Application

Figure 10-6. Materials Processes Utilization List

10.2.5 Fasteners

The developer shall comply with the procurement and test requirements for flight hardware and critical GSE fasteners contained in 541-PG-8072.1.2, Goddard Space Flight Center Fastener Integrity Requirements.

Fasteners made of plain carbon or low alloy steel shall be protected from corrosion. When plating is specified, it shall be compatible with the space environment. On steels harder than RC 33, a plating process that does not embrittle the steel shall be utilized.

No split ring or internal tooth lock washers are permitted on any flight hardware or GSE that will be vibration tested with flight hardware. Some locking feature is required for all flight fasteners.

10.3 MATERIALS USED IN "OFF-THE-SHELF-HARDWARE”

"Off-the-shelf hardware" for which a detailed materials list is not available and where the included materials cannot be easily identified and/or replaced shall be treated as non-compliant. The developer shall submit an MUA that defines the appropriate measures that will be used to ensure that all materials in the “off-the-shelf” hardware are acceptable for use. It may be possible to replace unknown or non-compliant materials within the hardware with compliant materials, or hermetically seal, or vacuum bake out the questionable hardware to bring the hardware into a suitable condition for use. Such approaches shall be documented in the MUA. When a vacuum bake-out is the selected method, it shall incorporate a quartz crystal microbalance (QCM) and cold finger to enable a determination of the duration and effectiveness of the bake-out as well as compliance with the project contamination plan and error budget.

10.4 MATERIALS PROCUREMENT REQUIREMENTS

Raw materials purchased by the developer shall be accompanied by a Certificate of Raw Materials Compliance and, where applicable, the results of nondestructive, chemical and physical tests. When requested, this information shall be made available to the Government for review.

10.4.1 Incoming Inspection Requirements

The developer shall perform, or be responsible for the performance of applicable incoming tests and inspections of materials to ensure that they meet the requirements of the procurement specification. Unless previously accomplished and accepted by Government or developer field personnel, incoming testing and inspections shall be performed upon receipt of the parts or materials. The inspection and testing of materials shall be conducted in accordance with a plan approved by the Government LDCM MAE.

10.5 SHELF-LIFE-CONTROL REQUIREMENTS FOR POLYMERIC MATERIALS

Polymeric materials that have a limited shelf life shall be controlled by a process that identifies the start date (manufacturing date, shipment date, or date of receipt, etc.), the storage conditions associated with a specified shelf life, and expiration date. Materials such as o-rings, rubber seals, tape, uncured polymers, lubricated bearings and paints shall be included. When a limited-life piece part is installed in a subassembly, the subassembly item shall be included in the Limited-Life Items List.

Materials usage beyond the expiration date requires that the developer demonstrate by means of appropriate testing that the material's properties are not compromised for the intended use. In these situations, a waiver shall be written and submitted to the Government for approval prior to use of the material beyond the expiration date.

10.6 FAILURE ANALYSIS

Failure analysis shall be performed on part and material failures experienced during assembly and testing as directed by the MRB. Failures shall be analyzed to the extent necessary to understand the failure mode and cause, to detect and correct out-of-control processes, to determine the necessary corrective actions, and to determine lot disposition. When required, a failure analysis report shall be prepared and documented. The developer shall determine and implement appropriate corrective action for each material and processes (M&P) failure. All failures, and the results of final failure analysis, shall be documented.

Failure analysis reports shall be retrievable for the duration of the contract, and shall be available to GSFC.

10.7 PRESERVATION AND PACKING

Preservation, packaging, and packing shall be in accordance with the item and the system requirements. All parts that are subject to degradation by ESD shall be packaged in accordance with the approved ESD procedures.

10.8 HANDLING

Handling (including storage) procedures shall be instituted to prevent part and material degradation. The handling procedures shall be retained through inspection, kitting, and assembly and shall be identified on "build to" documentation. The following criteria shall be used as a minimum for establishing handling and storage procedures for parts and materials:

a. Control of environment, such as temperature, humidity, contamination, and pressure.

b. Measures and facilities to segregate and protect parts and materials routed to different locations, such as to the materials review crib, to a laboratory for inspection, or returned to the manufacturer from unaccepted shipments.

c. Space quality parts shall be stored in identified containers.

d. Control measures to limit personnel access to parts and materials during receiving inspection and storage.

e. Facilities for interim storage of parts and materials.

f. Provisions for protective cushioning, as required, on storage area shelves, and in storage and transportation containers.

g. Protective features of transportation equipment design to prevent packages from being dropped or dislodged in transit.

h. Protective bench surfaces on which parts and materials are handled during operations such as test, assembly, inspection, and organizing kits.

i. Required use of gloves, finger cots, tweezers, or other means when handling parts to protect the parts from contact by bare hands.

j. Provisions for protection of parts susceptible to damage by ESD.

k. Unique parts and materials criteria.

10.9 DATA RETENTION

The developer shall maintain records of incoming inspection tests, lot qualification and acceptance test data, radiation hardness assurance test data, traceability data and other data as determined by the Government for a period of time specified by GSFC.

11.0 EEE PARTS CONTROL PROGRAM SUPPORT

11.1 GENERAL

The developer shall plan and implement an EEE Parts Control Program to assure that all parts selected for use in flight hardware meet mission objectives for quality and reliability. The program shall be in place to effectively support the design and selection processes for the duration of the contract. The Developer shall control the selection, application, evaluation, and acceptance of all parts through a Parts Control Board (PCB).

All parts shall be selected and processed in accordance with GSFC EEE-INST-002, “EEE Parts Selection, Screening Qualification and Derating,” for part quality level 2. Exceptions for use of a lesser grade part with additional testing shall be made on a case-by-case basis only when a level 2 part is not available. Such exceptions require approval by the PCB.

The Developer shall prepare a Parts Control Plan (PCP) (CDRL SA-18) describing the approach and methodology for implementing their Parts Control Program. The PCP shall also define the Developer’s criteria for parts selection and approval based on the guidelines of this section. The Developer Project Parts Engineer (PPE) shall work with the GSFC PPE to assure that all necessary information is contained in the PCP.

11.2 DEVELOPER’S PROJECT PARTS ENGINEER

The developer shall designate one key individual as the PPE, who shall have the prime responsibility for management of the EEE Parts Control Program. This individual shall have direct, independent and unimpeded access to the GSFC PPE and PCB. The PPE shall work with design engineers, radiation engineers, reliability engineers and the GSFC PPE to perform part selection and control.

Tasks performed by the developer PPE shall include but are not limited to the following:

1. Work with GSFC PPE team to perform parts control.
2. Provide PCB agenda, prepare Parts Lists and provide supporting part information for parts evaluation and approval by the PCB.
3. Coordinate Parts Control Board meetings, maintain minutes, develop and maintain the instrument Parts Identification List (PIL), develop the instrument portion of the Project Approved Parts List (PAPL), As-Designed Parts List (ADPL) and As-Built Parts List (ABPL).
4. Perform Customer Source Inspections (CSI) and audits at supplier facilities as required.
5. Prepare part procurement, screening, qualification, and modification specifications, as required.
6. Disposition/track part nonconformances and part failure investigations.

7. Track and report impact of Alerts and Advisories on flight hardware.

11.3 PARTS CONTROL BOARD

The developer shall establish a PCB or similar documented system to facilitate the management, selection, standardization, and control of parts and associated documentation for the duration of the contract. The PCB shall be responsible for the review and approval of all EEE parts, for conformance to established criteria as defined herein (including radiation effects), and for developing and maintaining a Project-Approved Parts List (PAPL). In addition, the PCB is responsible for providing assistance in all parts activities, such as part failure investigations, disposition of part non-conformances, and part problem resolutions. PCB operating procedures shall be included as part of the PCP.

11.3.1 PCB Responsibilities

The responsibilities of the PCB shall include, but not be limited to, the following:

- Evaluate EEE parts for conformance to established criteria and inclusion in the parts list.
- Develop and maintain a PAPL.
- Review and approve EEE part derating as necessary for unique applications.
- Define testing requirements.
- Review unique applications (including radiation effects).
- Track part failure investigations and non-conformances.

11.3.2 PCB Meetings, Notification, and Reports

PCB meetings shall be convened on a regular basis, and otherwise as needed. If agreeable by the Government, PCB meetings may be conducted via phone conversation. The GSFC PPE shall be a permanent member of PCB meetings. The developer PPE shall prepare meeting minutes to document all decisions made

The Developer PPE shall notify attendees at least two working days in advance of all upcoming meetings except in an emergency situation. Notification shall, at a minimum, include a proposed agenda and Parts Identification List (PIL) of candidate parts.

11.3.3 PCB Membership

At a minimum, the PCB membership shall consist of the developer's Product Assurance Manager, developer PPE, GSFC PPE, and GSFC Project Radiation Engineer (PRE) (GSFC Code 561) when required. The developer PPE and GSFC PPE shall participate in all PCB meetings. The GSFC LDCM Chief Safety and Mission Assurance Officer (CSO), or designee, may attend as necessary. The developer PPE shall assure that the appropriate individuals with engineering knowledge and skills are represented as necessary at meetings, such as part commodity specialists, radiation engineers, or the appropriate subsystem design engineer.

If there are any parts issues that cannot be resolved at the PCB level, the issues shall be elevated to the GSFC (LDCM) Project Manager for disposition.

11.4 PART SELECTION AND PROCESSING

All part commodities identified in EEE-INST-002 are considered EEE parts and shall be subjected to the requirements set forth in this section. EEE parts types that do not fall into any of the categories covered in EEE-INST-002 shall be reviewed by the Government on a case-by-case basis using the closest NASA, Defense Supply Center Columbus (DSCC), or government controlled specification. In the event a suitable government baseline specification does not exist, the developer PPE shall consult the GSFC PPE to identify the best available industry standard for that particular commodity, and develop appropriate procurement, screening and qualification specifications.

11.4.1 Parts Selection

Parts shall be selected from the GSFC EEE-INST-002, "Parts Selection, Screening, Qualification and Derating" document, or the NASA Parts Selection List (NPSL) for quality level 2 or better. Exceptions for use of a lower grade shall only be made by the Government on a case-by-case basis when a level 2 part is unavailable. Such exceptions require approval by PCB. The use of a lower grade part requires additional testing be performed in accordance with EEE-INST-002 to upgrade the part to level 2.

EEE-INST-002 contains value added testing for a number of parts listed in the NPSL. These tests include Particle Impact Noise Detection (PIND) testing for all EEE devices, surge current testing for tantalum capacitors and dielectric screening for several types of ceramic capacitors. These, and any other value added tests listed in EEE-INST-002, shall be performed to enhance the reliability of parts. PCB approval is required if there is any deviation from any screening or qualification tests as specified in EEE-INST-002.

11.4.2 Radiation Requirements for Parts Selection

All parts shall be selected to perform nominally in the predicted radiation environment, including the applicable Radiation Design Margin (RDM). The radiation environment causes the following three main degradation effects, which shall be accounted for in all active parts selection:

- Total Ionizing Dose (TID) (including Enhanced Low Dose Rate [ELDR] effects) – Parts shall be selected to ensure adequate performance in the application, up to a dose of twice the expected mission dose. Linear bipolar parts, including transistors, shall be assumed to be ELDR susceptible, unless the parts have been successfully tested and shown insensitive.

- Single-Event Effects (SEE) – Parts shall be assessed for the potential of Single-Event Upset (SEU) or Single-Event Transient (SET), which requires analysis of the circuit application on a case-by-case basis. Parts susceptible to Single-Event Latch-up (SEL) should be avoided. If performance demands the use of an SEL susceptible part, measures shall be implemented to ensure that SEL induced damages (both prompt and latent) are mitigated and that instrument performance is not compromised. These measures shall receive approval by the GSFC PRE and PPE before the part can be added to the PAPL. Applied voltages for power Metal-Oxide-Semiconductor Field Effect Transistors (MOSFETs), Field Effect Transistors (FETS), and bipolar junction transistors shall be in the safe operating ranges for these devices, based on Single-Event Gate Rupture (SEGR)/Single- Event Burn-out (SEB) test data.
- Displacement Damage – Parts shall be able to withstand the displacement damage to high energy protons, to twice the fluence expected in the predicted LDCM environment. This effect can cause significant damage in optical devices.

These effects and others may require individual part application analysis to be performed as determined by the GSFC PRE. The developer shall document the radiation analysis of each part as applicable.

11.4.3 Custom or Advanced Technology Devices

Devices such as custom hybrid microcircuits, detectors, Application Specific Integrated Circuits (ASICs), and MCMs shall be subject to parts control. These device types planned for first use in a space environment by the LDCM instrument developer shall also be subject to a design review appropriate for the individual technology. The design review shall include element evaluation to assure each element's reliability (review should include such items as burn-in, voltage conditioning, sample size, element derating, etc.), device construction and assembly process (including materials evaluation for such items as contamination concerns, metal whisker concerns, and adequate material thermal matching; materials specialists shall be consulted as necessary). A customer source inspection may be required if so determined by the Government.

A procurement specification may be required for parts in this category based on the determination of the Government PPE. These specifications shall fully describe the item being procured, and shall include physical, mechanical, environmental, electrical test requirements, and QA provisions necessary to control manufacture and acceptance. Screening requirements designated for the part shall be included in the procurement specification. Test conditions, burn-in circuits, failure criteria, and lot rejection criteria shall be included. For lot acceptance or rejection, the Percentage of Defectives Allowable (PDA) in a screened lot shall be in accordance with that prescribed in the closest military part specification.

11.4.4 Plastic Encapsulated Microcircuits

The use of Plastic Encapsulated Microcircuits (PEMs) and plastic semiconductors is discouraged, however, when use of PEMs is necessary to achieve unique performance requirements unachievable using hermetic high reliability microcircuits, plastic encapsulated parts shall meet the requirements of EEE-INST-002. The PCB shall review the procurement specification, application of part, and storage processes for PEMs, to assure that all aspects of EEE-INST-002 have been met.

11.4.5 Verification Testing

Re-performance of screening tests, which were performed by the manufacturer or authorized test house, as required by the military or procurement specification, are not required unless deemed necessary by failure history, GIDEP Alerts, age, or other reliability concerns. If required, testing shall be performed in accordance with GSFC EEE-INST-002, or as determined by the PCB.

11.4.6 Parts Approved on Prior Programs

Parts previously approved by GSFC for other projects via prior PCB activity or a Nonstandard Parts Approval Request (NSPAR) shall not be granted "grandfather approval" on LDCM. However, existing approval packages may be brought by the developer to the PCB as an aid to present candidate parts for approval. (Preparation of NSPARs is not a requirement for LDCM.)

11.5 PART ANALYSIS

11.5.1 Destructive Physical Analysis

A sample of each lot date code of Field Programmable Gate Arrays (FPGAs), microcircuits, hybrid microcircuits, oscillators, and semiconductor devices may be subjected to a Destructive Physical Analysis (DPA) based on PCB recommendation. All other parts may require a sample DPA if it is deemed necessary by the PCB as indicated by failure history, GIDEP Alerts, or other reliability concerns. DPA tests, procedures, sample size and criteria shall be as specified in GSFC specification S-311-M-70, "Destructive Physical Analysis", or MIL-STD-1580, "Destructive Physical Analysis for EEE Parts." If approved by the PCB, the developer's procedures for DPA may be used in place of S-311-M-70 and shall be submitted with the PCB for concurrence prior to use. The PCB shall consider variation to the DPA sample size requirements, due to part complexity, availability or cost on a case-by-case basis.

11.5.2 Failed EEE Parts

An EEE part failure is defined as a failure for which the part itself is the intrinsic cause, which occurs while the part is operating within its specification limits. Emphasis shall be placed on detection, analysis, and feedback of failure data during unit level testing. The developer shall have a method in place to report all EEE component failures. Failures occurring during EEE part screening and qualification shall be reported.

Failures that occur after the first application of power at the subassembly level (and continuing through unit, subsystem and system levels) during qualification and acceptance testing of flight hardware shall be reported. The failure reporting shall include identification of failed parts, notification within an approved time of failure, retrieval of failed/overstressed parts, part failure analysis, and documentation of all pertinent information related to each failure. The failure reporting plan shall be documented and presented to the PCB.

11.5.3 Failure Analysis

When a component part Failure Analysis (FA) is necessary to support a Failure Review Board (FRB), the developer shall prepare a part Failure Analysis Report. The contractor PPE shall submit the completed report to the PCB for review and approval in order to assure proper documentation is presented for the FRB. The failure report form shall provide the following information at a minimum:

- The failed part's identity (part name, part number, reference designator, manufacturer, manufacturing lot/date code, and part serial number if applicable), and symptoms by which the failure was identified (the conditions observed as opposed to those expected).
- The name of the unit or subsystem on which the failure occurred, date of failure, the test phase, and the environment in which the test was being conducted.
- An indication of whether the failure of the part or item in question constitutes a primary or secondary (collateral) failure (caused by another failure in the circuit and not a failure on its own merit).

The completed failure report shall include copies of any supporting photographs, X-rays, metallurgical data, microprobe or spectrographic data, Scanning Electronic Microscope (SEM) photographs, pertinent variables (electrical and radiation) data, etc. Radiation data shall be submitted where it is deemed relative to the failure mechanism.

11.6 ADDITIONAL REQUIREMENTS

11.6.1 Parts Age Control

All active EEE parts procured with date codes indicating that more than five years have elapsed from the date of manufacture to date of procurement shall be subjected to a re-screen (and sample DPA per PCB recommendation). Parts taken from user inventory older than five years do not require re-screen, provided they have been properly stored (refer to Section 13). Proper storage means maintaining the parts within their rated temperature and humidity range in an area protected from conditions that create electrostatic damage or contaminants that may affect their functionality (e.g. corrosive atmospheres that damage the plating on the leads or terminations). Storage areas shall be inspected and electrostatic discharge (ESD) certified for proper equipment and handling procedures in accordance with Chapter 13, "Electrostatic Discharge Control".

An alternate contractor method of controlling parts age may be used upon review and approval by the PCB.

Parts over ten years from the date of manufacture to date of procurement are discouraged. Exceptions shall be reviewed on a case-by-case basis and require approval of the PCB. Parts stored in uncontrolled conditions where they may be exposed to ESD, the elements, or sources of contamination shall not be used.

11.6.2 Derating

All EEE parts shall be used in accordance with the derating guidelines of GSFC EEE-INST-002. As determined by the Government, the developer's derating policy may be used in place of the GSFC guidelines and shall be submitted with the developer PCP for approval. The developer shall maintain documentation on parts derating analysis and make it available for GSFC review.

11.6.3 Alerts

The developer shall be responsible for the review and disposition of all GIDEP Alerts on parts proposed for flight use. In addition, any NASA Alerts and Advisories provided to the developer by GSFC shall be reviewed and dispositioned. Alert applicability, impact, and corrective actions shall be continuously documented and reported to GSFC. The review process shall continue from delivery to launch.

11.6.4 Prohibited Metals

Pure tin plating shall not be used in the construction and surface finish of EEE parts proposed for space hardware. Only alloys containing less than 97% tin are acceptable.

The use of pure cadmium or zinc is prohibited in the construction and surface finish of space hardware. All cadmium alloys or zinc alloys (e.g. brass) must be completely over plated with an approved metal. The GSFC Materials Branch shall be consulted as necessary.

11.7 PARTS LIST

The developer shall develop and maintain a Parts Identification List (PIL), Project Approved Parts List (PAPL) and As-Designed Parts List (ADPL) for the duration of the project. The developer shall obtain PCB approval for listing parts on the PAPL before initiation of procurement activity. All submissions to the LDCM Project shall include a searchable electronic compatible form (Microsoft Excel, Microsoft Access, etc.; consult GSFC PPE for acceptable format).

11.7.1 Parts Identification List

The PIL shall be a real time working list of all parts proposed for use in flight hardware. The PIL is prepared from design team inputs or subcontractor inputs, and is used for presenting and tracking candidate parts to the PCB. The PIL shall include the following information at a minimum: part number, part name or description, manufacturer, manufacturer's generic part number, drawing number, specifications, Federal Stock Class (FSC), comments as necessary (to indicate problems, long lead times, additional testing imposed, application unique notes, etc). The PIL shall also have radiation effects information on active devices such as semiconductors, microcircuits and optoelectronic parts. (CDRL SA-19)

11.7.2 Program Approved Parts List

The PAPL shall be the only listing of approved parts for flight hardware, and shall be the combined listing of all parts submitted through PILs that are approved by the PCB, plus approval status and disposition notes. Only parts that have been evaluated and approved by the PCB shall be listed in the PAPL. The PCB shall assure standardization of parts listed in the PIL across various systems and subsystems. (CDRL SA-19)

11.7.3 As-Designed Parts List

The developer PPE shall establish an As-Designed Parts List (ADPL) as soon as practical after the preliminary design release. The GSFC PPE will maintain a copy in the GSFC Parts Database, and will work with the design teams to keep the list(s) current.

11.7.4 As-Built Parts List

An As-Built Parts List (ABPL) shall also be prepared and submitted to the LDCM by the Contractor PPE. The ABPL is generally a final compilation of all parts as installed in flight equipment, with additional "as-installed" part information such as manufacturer name, Commercial and Government Entity (CAGE) code, Lot-Date code, part serial number (if applicable), box identification and/or part location. Provisions shall be in place to find quantity used and provide traceability to box or board location through build paperwork. The manufacturer's plant specific CAGE code is preferred, but if unknown, the supplier's general CAGE code is sufficient. (CDRL SA-19)

11.8 DATA REQUIREMENTS

Attributes summary data shall be kept available to GSFC for all testing performed. Variable data (read and record) shall be recorded for initial, interim and final electrical test points and shall be kept available to GSFC.

For flight lots with samples subjected to Radiation Lot Acceptance Test (RLAT), the radiation report that identifies parameter degradation behavior shall be provided to the PCB, and variables data acquired during radiation testing shall be kept available to GSFC.

11.8.1 Data Retention

The developer shall have a method in place for retention of data generated for parts tested and used in flight hardware. The data shall be kept on file in order to facilitate future risk assessment and technical evaluation. In addition, the developer shall retain all part functional failures, all destructive and non-flight non-destructive test samples, which could be used for future validation of parts for performance under certain conditions not previously accounted for. These devices shall be kept until launch. Data shall be retained for the useful life of the mission, unless otherwise permitted by PCB.

All historical records and data required to support these records shall be retained for a period of five years and shall be provided to GSFC on request.

12.0 CONTAMINATION CONTROL REQUIREMENTS

12.1 GENERAL

The developer shall plan and implement a contamination control program appropriate for the hardware. The program shall establish the specific cleanliness requirements and delineate the approaches to be followed in a Contamination Control Plan (CCP).

Contamination includes all materials of molecular and particulate nature whose presence degrades hardware performance. The source of the contaminant materials may be the hardware itself, the test facilities, and the environments to which the hardware is exposed.

12.2 CONTAMINATION CONTROL VERIFICATION PROCESS

The developer shall develop a contamination control verification process. The verification process shall be performed in order:

a. Determination of contamination sensitivity.

b. Determination of a contamination allowance.

c. Determination of a contamination budget.

d. Development and implementation of a contamination control plan.

Each of the above activities shall be documented and submitted to GSFC for concurrence/approval.

12.3 CONTAMINATION CONTROL PLAN

The developer shall prepare a CCP that describes the procedures that will be followed to control contamination (CDRL SA-17). It shall establish the implementation and describe the methods that will be used to measure and maintain the levels of cleanliness required during each of the various phases of the item's lifetime. In general, all mission hardware shall be compatible with the most contamination-sensitive components.

12.4 MATERIAL OUTGASSING

In accordance with ASTM E595, NASA RP 1124 shall be used as a guide. Individual material outgassing data shall be established based on each component's operating conditions. Established material outgassing data shall be verified and shall be reviewed by GSFC.

12.5 THERMAL VACUUM BAKEOUT

The developer shall perform thermal vacuum bakeouts of all hardware as required by the CCP. The parameters of such bakeouts (e.g., temperature, duration, outgassing requirements, and pressure) shall be individualized depending on materials used, the fabrication environment, and the established contamination allowance. Thermal vacuum bakeout results shall be verified and shall be submitted to GSFC for review.

12.6 HARDWARE HANDLING

The developer shall practice cleanroom standards in handling hardware. The contamination potential of material and equipment used in cleaning, handling, packaging, tent enclosures, shipping containers, bagging (e.g., anti-static film materials), and purging shall be described in detail for each subsystem or component at each phase of assembly, integration, test, and launch.

13.0 ELECTROSTATIC DISCHARGE CONTROL

13.1 GENERAL

The developer shall document and implement an ESD Control Program to assure that all manufacturing, inspection, testing, and other processes will not compromise mission objectives for quality and reliability due to ESD events.

13.2 APPLICABLE DOCUMENTS

GSFC-WM-001 Workmanship Manual For Electrostatic Discharge Control (Excluding Electrically Initiated Explosive Devices)

13.3 ELECTROSTATIC DISCHARGE CONTROL REQUIREMENTS

The developer shall document and implement an ESD Control Program in accordance with GSFC-WM-001, Workmanship Manual For Electrostatic Discharge Control (Excluding Electrically Initiated Explosive Devices) or approved equivalent implementation of ANSI/ESD S20.20, "Protection of Electrical and Electronic Parts, Assemblies and Equipment (excluding electrically initiated explosive devices)." This implementation shall be suitable to protect the most sensitive component involved in the project. At a minimum, the ESD Control Program shall address training, protected work area procedures and verification schedules, packaging, facility maintenance, storage, and shipping.

All personnel who manufacture, inspect, test, otherwise process electronic hardware, or require unescorted access into ESD protected areas shall be certified as having completed the required training, appropriate to their involvement prior to handling any electronic hardware.

Electronic hardware shall be manufactured, inspected, tested, or otherwise processed only at designated ESD protective work areas. These work areas shall be verified on a regular schedule as identified in the developer's ESD Control Program or an ESD Control Program that has been approved by the procuring organization.

Electronic hardware shall be properly packaged in ESD protective packaging at all times when not actively being manufactured, inspected, tested, or otherwise processed.

Alternate standards may be proposed by the developer. Their use is limited to the specific project and is allowed only after they have been reviewed and approved by the GSFC Project Office.

Materials selected for packaging or protecting ESD sensitive devices shall not leach chemicals, leave residues, or otherwise contaminate parts or assemblies (e.g., "pink poly" is well known for its outgassing of contaminants and should only be used for storing documentation or other non-hardware uses).

14.0 GIDEP ALERTS AND PROBLEM ADVISORIES

14.1 GENERAL

The developer shall participate in the GIDEP in accordance with the requirements of the GIDEP S0300-BT-PRO-010 ("GIDEP Operations Manual") and S0300-BU-GYD-010 ("Government-Industry Data Exchange Program Requirements Guide"), available from the GIDEP Operations Center, Post Office (PO) Box 8000, Corona, California 92878-8000.

The developer shall review all GIDEP Alerts, GIDEP Safe-Alerts, GIDEP Problem Advisories, GIDEP Agency Action Notices, NASA Advisories and any informally documented component issues presented by Code 303, to determine if they affect the developer products produced for NASA. For the above mentioned alerts and advisories that are determined to affect the program, the developer shall take action to eliminate or mitigate any negative effect to an acceptable level.

The developer shall provide a matrix that shows whether or not GIDEPs and related alerts impact their hardware and this matrix shall be maintained and updated as new alerts are issued or new hardware is received. It is the developers' responsibility to review and update this matrix beginning prior to Critical Design Review (CDR) and continuing until final acceptance of the instrument.

The developer shall generate the appropriate failure experience data report(s) (GIDEP Alert, GIDEP Safe-Alert, GIDEP Problem Advisory) on a monthly basis, in accordance with the requirements of GIDEP S0300-BT-PRO-010 and S0300-BU-GYD-010 whenever failed or nonconforming items, available to other buyers, are discovered during the course of the contract.

15.0 APPLICABLE DOCUMENTS LIST

DOCUMENT	DOCUMENT TITLE
AFSCM 91-710	Range Safety Users Requirements Manual
ANSI/ASQC Q9000-3	Quality Management and Quality Assurance Standards – Part 3: Guidelines for the Application of ISO 9001 to the Development, Supply and Maintenance of Software
ANSI/ESD S20.20	ESD Association Standard for the Development of an Electrostatic Discharge Control Program for protection of electrical and electronic parts, assemblies, and equipment
ANSI/ISO/ASQ Q9001:2000	American National Standard Quality Systems - Model for Quality Assurance in Design, Development, Production, Installation and Servicing
ANSI/IPC-A-600	Acceptability of Printed Boards
ASTM E-595	Standard Test Method for Total Mass Loss and Collected Volatile Condensable Materials from Outgassing in a Vacuum Environment
FAR	Federal Acquisition Regulations
GIDEP S0300-BT-PRO-010	GIDEP Operations Manual
GIDEP S0300-BU-GYD-010	Government-Industry Data Exchange Program Requirements Guide
GMI 1700.2	Goddard Space Flight Center Health, and Safety Program
GPR 1060.2	Management Review and Reporting for Programs and Projects
GPR 8621.1	Reporting of Mishaps, Incidents, Hazards, and Close Calls
GPR 8621.2	Processing Mishap, Incident, Hazard, and Close Call Reports
GPR 8621.3	Mishap, Incident, Hazard, and Close Call Investigation
GPR 8700.4	Technical Review Program
GPR 8700.6	Engineering Peer Reviews
GSFC-STD-7000	General Environmental Verification Standards (GEVS) for Flight Programs and Projects

GSFC S-312-P003	Procurement Specification for Rigid Printed Boards for Space Applications and Other High Reliability Uses
GSFC EEE-INST-002	Instructions for EEE Parts Selection, Screening, and Qualification and Derating
GSFC-WM-001	Workmanship Manual For Electrostatic Discharge Control (Excluding Electrically Initiated Explosive Devices)
IEEE STD 610.12	IEEE Standard Glossary for Software Engineering Terminology
IEEE STD 730	IEEE Standard for Software Quality Assurance Plans
IEEE STD 982.1	IEEE Standard Dictionary of Measures to Produce Reliable Software
IEEE STD 982.2	IEEE Guide for the Use of IEEE Standard Dictionary of Measures to Produce Reliable Software
IPC A-600	Acceptability of Printed Boards
IPC/EIA J-STD-001	Requirements for Soldered Electrical and Electronic Assemblies
IPC-2221	Generic Standard on Printed Board Design
IPC-2222	Sectional Design Standard for Rigid Organic Printed Boards
IPC-2223	Sectional Design Standard for Flexible Printed Boards
IPC-6011	Generic Performance Specifications for Printed Boards
IPC-6012	Qualification and Performance Specification for Rigid Printed Boards
IPC-6013	Qualification and Performance Specification for Flexible Printed Boards
IPC-6018	Microwave End Product Board Inspection and Test
ISO 17025	General Requirements for the Competence of Testing and Calibration Laboratories
KHB 1860.1	KSC Ionizing Radiation Protection Program
KHB 1860.2	KSC Non-Ionizing Radiation Protection Program
KNPR 8715.3	KSC Safety Practices Procedural Requirements

MIL-HDBK-217	Reliability Prediction of Electronic Equipment
MIL-HDBK-470	Designing and Developing Maintainable Products and Systems
MIL-HDBK-472	Maintainability Prediction
MIL-PRF-19500	General Specification for Semiconductor Devices
MIL-PRF-38534	General Specification for Hybrid Microcircuits
MIL-PRF-38535	General Specification for Integrated Circuits (Microcircuits) Manufacturing
MIL-PRF-55365	General Specification for Established Reliability and Nonestablished Reliability of (Tantalum) Chip Fixed Electrolytic Capacitors
MIL-STD-461	Electromagnetic Emission and Susceptibility Requirement for Control of Electromagnetic Interference
MIL-STD-756	Reliability Modeling and Prediction
MIL-STD-882	System Safety Program Requirements
MIL-STD-883	DoD Test Method Standards for Microcircuits
MIL-STD-981	Design, Manufacturing and Quality Standards for Custom Electromagnetic Devices for Space Applications
MIL-STD-1629	Procedures for Performing a Failure Mode Effects and Criticality Analysis
MSFC 3029	Guidelines for the Selection of Metallic Materials for Stress Corrosion Cracking Resistance in Sodium Chloride Environments
MSFC CR 5320.9	Payload and Experiment Failure Mode Effects Analysis and Critical Items List Ground Rules
MSFC-HDBK-527	Material Selection List for Space Hardware Systems
NASA RP-1124	Outgassing Data for Selecting Spacecraft Materials
NASA RP-1161	Evaluation of Multi-Layer Printed Wiring Boards by Metallographic Techniques
NFS 1815.201	NASA Federal Acquisition Regulation Supplement Exchanges with Industry before Receipt of Proposals

NFS 1823.7001	NASA Federal Acquisition Regulation Supplement Safety and Health NASA Solicitation Provisions and Contract Clauses
NFS 1815.305	NASA Federal Acquisition Regulation Supplement Source Selection Proposal Evaluation
NFS 1846.401	NASA Federal Acquisition Regulation Supplement Government Contract Quality Assurance General
NHB 1700.1	NASA Safety Policy and Requirements Document
NPD 7120.4	Program and Project Management
NPD 8700.1	NASA Policy for Safety & Mission Success
NPD 8710.2	NASA Safety and Health Program Policy
NPR 5100.4	NASA FAR Supplement
NPR 7120.5	NASA Program and Project Management Processes and Requirements
NPR 7150.2	NASA Software Engineering Requirements
NPR 8000.4	Risk Management Procedural Requirements
NPR 8621.1	NASA Procedures and Guidelines for Mishap Reporting, Investigating, and Record Keeping
NPR 8715.3	NASA Safety Manual
NPR 8715.6	NASA Procedural Requirements for Limiting Orbital Debris
NASA-STD 8719.8	Expendable Launch Vehicle Payloads Safety Review Process Standard
NASA-STD 8719.9	NASA Standard for Lifting Devices and Equipment
NASA-STD 8719.13	NASA Software Safety Standard
NASA-STD 8719.14	Guidelines and Assessment Procedures for Limiting Orbital Debris
NASA-STD 8739.1	Workmanship Standard for Staking and Conformal Coating of Printed Wiring Boards and Electronic Assemblies
NASA-STD 8739.2	Workmanship Standard for Surface Mount Technology
NASA-STD 8739.3	Workmanship Standard for Soldered Electrical Connections

NASA-STD 8739.4	Workmanship Standard for Crimping, Interconnecting Cables, Harnesses and Wiring
NASA-STD-8739.5	Workmanship Standard for Fiber Optic Terminations, Cable Assemblies and Installation
NSS 1740.14	Guidelines and Assessment Procedures for Limiting Orbital Debris
S-302-89-01	Procedures for Performing a Failure Mode and Effects Analysis
S-311-M-70	Specification for Destructive Physical Analysis
SAE AS9100	Aerospace Standard, Quality Systems Model for Quality Assurance, Design, Development, Production, Installation and Servicing
SAE JA1002	Software Reliability Program Standard
300-PG-7120.2.1	Mission Assurance Guidelines (MAG) Implementation
302-PG-7120.2.1	Mission Assurance Guidelines Implementation
541-PG-8072.1.2	GSFC Fastener Integrity Requirements
540-PG-8715.1.1	Mechanical Systems Division Safety Manual, Volume I
540-PG-8715.1.2	Mechanical Systems Division Safety Manual, Volume II

Appendix A. Abbreviations and Acronyms

Abbreviation/ Acronym	DEFINITION
ABPL	As-Built Parts List
ABML	As-Built Materials List
ADMPL	As-Designed Materials and Processes List
AFSPC	Air Force Space Command
ANSI	American National Standards Institute
AR	Acceptance Review
ASIC	Application Specific Integrated Circuits
ASQ	American Society for Quality
ASQC	American Society for Quality Control
ASTM	American Society for Testing of Materials
BB	Ball Bearing
BGA	Ball Grid Array
C	Centigrade
CAGE	Commercial and Government Entity
CCB	Configuration Control Board
CCP	Contamination Control Plan
CCR	Configuration Change Request
CDR	Critical Design Review
CDRL	Contract Delivery Requirements List
CFR	Code of Federal Regulations
CIL	Critical Items List
CM	Configuration Management
CMO	Configuration Management Office
CO	Continuous Oscillation
COB	Chip on Board
COTR	Contracting Officer Technical Representative
COTS	Commercial Off-the-Shelf
CPM	Centimeters per minute
CRM	Continuous Risk Management
CRMS	Continuous Risk Management System
CS	Continuous Sliding
CSCI	Computer Software Configuration Item
CUR	Continuous Unidirectional Rotation
CVCM	Collected Volatile Condensable Mass
DID	Data Item Description
DoD	Department of Defense

Abbreviation/ Acronym	DEFINITION
DOORS	Dynamic Object Oriented Requirements System
DPA	Destructive Physical Analysis
DSCC	Defense Supply Center Columbus
EEE	Electrical, Electronic, and Electromechanical
EIA	Electronics Industry Alliance
EIDP	End Item Data Package
EIS	Environmental Impact Statement
ELDR	Enhanced Low Dose Rate
ELV	Expendable Launch Vehicle
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
ESD	Electrostatic Discharge
ESMD	Exploration Systems Mission Directorate
ETA	Event Tree Analysis
ETM	Environmental Test Matrix
ETR	Eastern Test Range
EVA	Extravehicular Activity
EWR	Eastern and Western Test Ranges
FA	Failure Analysis
FAP	Flight Assurance Procedure
FAR	Federal Acquisition Regulations
FCA	Functional Configuration Audit
FETs	Field Effect Transistors
FMEA	Failure Modes and Effects Analysis
FOR	Flight Operations Review
FRB	Failure Review Board
FRR	Flight Readiness Review
FTA	Fault Tree Analysis
FY	Fiscal Year
G	Gears
GDS	Ground Data System
GEVS	General Environmental Verification Standards
GFE	Government-Furnished Equipment
GHB	Goddard Space Flight Center Handbook
GIA	Government Inspection Agency
GIDEP	Government Industry Data Exchange Program
GMI	Goddard Management Instruction
GOTS	Government Off-the-Shelf
GPMC	Governing Program Management Council

Abbreviation/ Acronym	DEFINITION
GPR	Goddard Procedure and Guidelines
GSE	Ground Support Equipment
GSFC	Goddard Space Flight Center
hrs	hours
HTL	Hazard Tracking Log
HQ	Headquarters
I&T	Integration and Test
IAC	Independent Assurance Contractor
IEEE	Institute of Electrical and Electronics Engineers
IIR	Integrated Independent Review
IIRT	Integrated Independent Review Team
INST	Instruction
IO	Intermittent Oscillation
IPC	Association Connecting Electronics Industries
IR	Intermittent Rotation
IS	Intermittent Sliding
ISO	International Organization for Standardization
IV&V	Independent Verification and Validation
JSC	Johnson Space Center
KHB	Kennedy Space Center Handbook
KSC	Kennedy Space Center
LAO	Large Angle Oscillation
LDCM	Landsat Data Continuity Mission
LRU	Line Replaceable Unit
M	Million
M&P	Materials and Processes
M&PCP	Materials and Processes Control Program
MAE	Materials Assurance Engineer
MAG	Mission Assurance Guidelines
MCM	Multi-Chip Module
MEB	Materials Engineering Branch
MIL	Materials Identification List
MLD	Master Logic Diagram
mm	millimeter
MOR	Mission Operations Review
MOSFETs	Metal-Oxide-Semiconductor Field Effect Transistors
MOTS	Modified Off-the-Shelf
MPCP	Materials and Processes Control Plan
MRB	Materials Review Board

Abbreviation/ Acronym	DEFINITION
MRR	Mission Readiness Review
MSFC	Marshall Space Flight Center
MSPSP	Missile System Pre-Launch Safety Data Package
MSR	Monthly Status Review
MUA	Materials Usage Agreement
NASA	National Aeronautics and Space Administration
NCR	Nonconformance Report
NHB	NASA Handbook
NPD	NASA Policy Directive
NPR	NASA Procedural Requirements
NPSL	NASA Parts Selection List
NSF	NASA Federal Supplement
NSPAR	Nonstandard Parts Approval Request
NSS	NASA Safety Standard
O_2	Oxygen
O&SHA	Operating and Support Hazard Analysis
ODA	Orbital Debris Assessment
OHA	Operational Hazard Analysis
OPM	Oscillation per minute
OSSMA	Office of Systems Safety and Mission Assurance
PAPL	Project Approved Parts List
PCA	Physical Configuration Audit
PCB	Parts Control Board
PCP	Parts Control Plan
PDA	Percentage of Defective Allowable
PDR	Preliminary Design Review
PEM	Plastic Encapsulated Microcircuit
PER	Pre-Environmental Review
PFR	Problem/Failure Report
PG	Procedures and Guidelines
PHA	Preliminary Hazards Analysis
PIL	Parts Identification List
PIND	Particle Impact Noise Detection
POCC	Payload Operations Control Center
PPE	Project Parts Engineer
PPL	Preferred Parts List
PQR	Procedure Qualification Record
PRA	Probabilistic Risk Assessment
PRE	Project Radiation Engineer

Abbreviation/ Acronym	DEFINITION
PSM	Project Safety Manager
PSR	Pre-Shipment Review
PSSSMA	Performance Specification Sheet for Space and Military Avionics
PTFE	Polytetrafluoroethylene
PWB	Printed Wiring Board
PWQ	Process Waste Questionnaire
QA	Quality Assurance
QCM	Quartz Crystal Microbalance
QMS	Quality Management System
R&M	Reliability and Maintainability
RBAM	Risk-Based Acquisition Management
RDM	Radiation Design Margin
RF	Radio Frequency
RFA	Request for Action
RLAT	Radiation Lot Acceptance Test
RMP	Risk Management Plan
RPP	Reliability Program Plan
RPM	Revolutions Per Minute
RVM	Requirements Verification matrix
SAE	Society of Automotive Engineers
SAM	System Assurance Manager
SAO	Small Angle Oscillation
SAR	Safety Assessment Report
SB	Sleeve Bearings
SC	Spacecraft
SCC	Stress Corrosion Cracking
SCM	Software Configuration Management
SCR	System Concept Review
SEB	Single-Event Burn-Out
SEC	Sliding Electrical Contacts
SEGR	Single-Event Gate Rupture
SEE	Single-Even Effects
SEL	Single-Event Latch up
SEM	Scanning Electronic Microscope
SET	Single-Event Transient
SEU	Single-Event Upset
SHA	System Hazard Analysis
SMA	Safety and Mission Assurance
SOW	Statement of Work

Abbreviation/ Acronym	DEFINITION
SRO	Systems Review Office
SRP	System Review Program
SRR	System Requirements Review
SS	Sliding Surface
SSHA	Subsystem Safety Hazard Analysis
SSPP	System Safety Program Plan
STD	Standard
STS	Space Transportation System
STT	Strategy-to-Task-to-Technology
SWG	Safety Working Group
SWRR	Software Requirements Review
TID	Total Ionizing Dose
TIG	tungsten inert gas
TIM	Technical Interface Meeting
TML	Total Mass Loss
TRR	Test Readiness Review
U.S.	United States
UV	Ultraviolet
V&V	Verification and Validation
VDD	Version Description Document
VTL	Verification Tracking Log
WOA	Work Order Authorization

Appendix B. Glossary/Definitions

The following definitions apply within the context of this document:

Acceptance Tests: The validation process that demonstrates that hardware is acceptable for flight. It also serves as a quality control screen to detect deficiencies and, normally, to provide the basis for delivery of an item under terms of a contract.

Assembly: See Level of Assembly.

Audit: A review of the developer's or sub-developer's documentation or hardware to verify that it complies with project requirements.

Collected Volatile Condensable Material (CVCM): The quantity of outgassed matter from a test specimen that condenses on a collector maintained at a specific constant temperature for a specified time.

Component: See Level of Assembly.

Configuration: The functional and physical characteristics of the payload and all its integral parts, assemblies, and systems capable of fulfilling the fit, form and functional requirements defined by performance specifications and engineering drawings.

Configuration Control: The systematic evaluation, coordination, and formal approval/disapproval of proposed changes, including the implementation of all approved changes to the design and production of an item with a configuration formally approved by the developer/purchaser/both.

Configuration Management (CM): The systematic control and evaluation of all changes to baseline documentation and subsequent changes to that documentation which define the original scope of effort to be accomplished (contract and reference documentation) and the systematic control, identification, status accounting and verification of all configuration items.

Contamination: The presence of materials of molecular or particulate nature, which degrade the performance of hardware.

Derating: The reduction of the applied load (or rating) of a device to improve reliability or to permit operation at high ambient temperatures.

Design Specification: Generic designation for a specification that describes functional and physical requirements for an article, usually at the component level or higher levels of assembly. In its initial form, the design specification is a statement of functional requirements with only general coverage of physical and test requirements.

The design specification evolves through the project life cycle to reflect progressive refinements in performance, design, configuration, and test requirements. In many projects, the end-item specifications serve all the purposes of design specifications for the contract end-items. Design specifications provide the basis for technical and engineering management control.

Designated Representative: An individual (such as a NASA plant representative), firm (such as assessment developer), Department of Defense (DoD) plant representative, or other government representative designated and authorized by NASA to perform a specific function for NASA. As related to the developer's effort, this may include evaluation, assessment, design review, participation, and review/approval of certain documents or actions.

Destructive Physical Analysis (DPA): An internal destructive examination of a finished part or device to assess design, workmanship, assembly, and any other processing associated with fabrication of the part.

Design Qualification Tests: Tests intended to demonstrate that an item will function within performance specifications under simulated conditions more severe than those expected from ground handling, launch, and orbital operations. Their purpose is to uncover deficiencies in design and method of manufacture. They are not intended to exceed design safety margins or to introduce unrealistic modes of failure. The design qualification tests may be to either "prototype" or "protoflight" test levels.

Discrepancy: See Nonconformance.

Electromagnetic Compatibility (EMC): The condition that prevails when various electronic devices are performing their functions according to design in a common electromagnetic environment.

Electromagnetic Interference (EMI): Electromagnetic energy, which interrupts, obstructs, or otherwise degrades or limits the effective performance of electrical equipment.

Electromagnetic Susceptibility: Undesired response by a component, subsystem, or system to conducted or radiated electromagnetic emissions.

End-to-End Tests: Tests performed on the integrated ground and flight system, including all elements of the payload, its control, stimulation, communications, and data processing to demonstrate that the entire system is operating in a manner to fulfill all mission requirements and objectives.

Failure: A departure from specification that is discovered in the functioning or operation of the hardware or software. See nonconformance.

Failure Modes, Effects, and Criticality Analysis (FMECA): A procedure by which each credible failure mode of each item from a low indenture level to the highest is analyzed to determine the effects on the system and to classify each potential failure mode in accordance with the severity of its effect.

Flight Acceptance: See Acceptance Tests.

Fracture Control Program: A systematic project activity to ensure that a payload intended for flight has sufficient structural integrity as to present no critical or catastrophic hazard. Also, to ensure quality of performance in the structural area for any payload (spacecraft) project. Central to the program is fracture control analysis, which includes the concepts of fail-safe and safe-life, defined as follows:

a. *Fail-safe:* Ensures that a structural element, because of structural redundancy, will not cause collapse of the remaining structure or have any detrimental effects on mission performance.

b. *Safe-life:* Ensures that the largest flaw that could remain undetected after non-destructive examination would not grow to failure during the mission.

Functional Tests: The operation of a unit in accordance with a defined operational procedure to determine whether performance is within the specified requirements.

Hardware: As used in this document, there are two major categories of hardware as follows:

a. *Prototype Hardware:* Hardware of a new design; it is subject to a design qualification test program and is not intended for flight.

b. *Flight Hardware:* Hardware to be used operationally in space. It includes the following subsets:

   (i) Protoflight Hardware: Flight hardware of a new design, subject to a qualification test program that combines elements of prototype and flight acceptance verification; that is, the application of design qualification test levels and duration of flight acceptance tests.

   (ii) Follow-On Hardware: Flight hardware built in accordance with a design that has been qualified either as prototype or as protoflight hardware; follow-on hardware is subject to a flight acceptance test program.

   (iii) Spare Hardware: Hardware whose design has been proven in a design qualification test program, subject to a flight acceptance test program and used to replace flight hardware that is no longer acceptable for flight.

   (iv) Re-flight Hardware: Flight hardware that has been used operationally in space and is to be reused in the same way; the validation program to which it is subject depends on its past performance, current status, and the upcoming mission.

Inspection: The process of measuring, examining, gauging, or otherwise comparing an article or service with specified requirements.

Instrument: See Level of Assembly.

Level of Assembly: The environmental test requirements of LEVR generally start at the component or unit-level assembly and continue hardware/software build through the system level (referred to in LEVR as the payload or spacecraft level). The assurance program includes the part level. Verification testing may also include testing at the assembly and subassembly levels of assembly; for test recordkeeping these levels are combined into a “subassembly” level.

The verification program continues through launch, and on-orbit performance. The following levels of assembly are used for describing test and analysis configurations:

a. *Part:* A hardware element that is not normally subject to further subdivision or disassembly without destruction of design use. Examples include resistor, integrated circuit, relay, connector, bolt, and gaskets.

b. *Subassembly:* A subdivision of an assembly. Examples are wire harness and loaded printed circuit boards.

c. *Assembly:* A functional subdivision of a component consisting of parts or subassemblies that perform functions necessary for the operation of the component as a whole. Examples are a power amplifier and gyroscope.

d. *Component or unit:* A functional subdivision of a subsystem and generally a self-contained combination of items performing a function necessary for the subsystem's operation. Examples are electronic box, transmitter, gyro package, actuator, motor, battery. For the purposes of this document, "component" and "unit" are used interchangeably.

e. *Section:* A structurally integrated set of components and integrating hardware that form a subdivision of a subsystem, module, etc. A section forms a testable level of assembly, such as components/units mounted into a structural mounting tray or panel-like assembly, or components that are stacked.

f. *Subsystem:* A functional subdivision of a payload consisting of two or more components. Examples are structural, attitude control, electrical power, and communication subsystems. Also included as subsystems of the payload are the science instruments or experiments.

g. *Instrument*: A spacecraft subsystem consisting of sensors and associated hardware for making measurements or observations in space. For the purposes of this document, an instrument is considered a subsystem (of the spacecraft).

h. *Module:* A major subdivision of the payload that is viewed as a physical and functional entity for the purposes of analysis, manufacturing, testing, and record keeping. Examples include spacecraft bus, science payload and upper stage vehicle.

i. *Payload:* An integrated assemblage of modules, subsystems, etc., designed to perform a specified mission in space. For the purposes of this document, "payload" and "spacecraft" are used interchangeably. Other terms used to designate this level of assembly are Laboratory, Observatory, and satellite.

j. *Spacecraft:* See Payload. Other terms used to designate this level of assembly are Laboratory, Observatory, and satellite.

Limit Level: The maximum expected flight.

Limited Life Items: Spaceflight hardware that (1) has an expected failure-free life that is less than the projected mission life, when considering cumulative ground operation, storage and on-orbit operation, and (2) has limited shelf life material used to fabricate flight hardware.

Maintainability: A measure of the ease and rapidity with which a system or equipment can be restored to operational status following a failure. It is characteristic of equipment design and installation, personnel availability in the required skill levels, adequacy of maintenance procedures and test equipment, and the physical environment under which maintenance is performed.

Margin: The amount by which hardware capability exceeds mission requirements.

Mission Assurance: The integrated use of the tasks of system safety, reliability assurance engineering, maintainability engineering, mission environmental engineering, materials and processes engineering, electronic parts engineering, quality assurance, software assurance, configuration management, and risk management to support NASA projects.

Module: See Level of Assembly.

Monitor: To keep track of the progress of a performance assurance activity; the monitor need not be present at the scene during the entire course of the activity, but will review resulting data or other associated documentation (see Witness).

Nonconformance: A condition of any hardware, software, material, or service in which one or more characteristics do not conform to requirements. As applied in quality assurance, nonconformances fall into two categories – discrepancies and failures. A discrepancy is a departure from specification that is detected during inspection or process control testing, etc., while the hardware or software is not functioning or operating. A failure is a departure from specification that is discovered in the functioning or operation of the hardware or software.

Offgassing: The emanation of volatile matter of any kind from materials into a manned pressurized volume.

Outgassing: The emanation of volatile materials under vacuum conditions resulting in a mass loss and/or material condensation on nearby surfaces.

Part: See Level of Assembly.

Payload: See Level of Assembly.

Performance Verification: Determination by test, analysis, or a combination of the two that the payload element can operate as intended in a particular mission; this includes being satisfied that the design of the payload or element has been qualified and that the particular item has been accepted as true to the design and ready for flight operations.

Protoflight Testing: See Hardware.

Prototype Testing: See Hardware.

Qualification: See Design Qualification Tests.

Red Tag/Green Tag: Physical tags affixed to flight hardware that mean: red (remove before flight) and green (enable before flight).

Redundancy (of design): The use of more than one independent means of accomplishing a given function.

Reliability: The probability that an item will perform its intended function for a specified interval under stated conditions.

Repair: A corrective maintenance action performed as a result of a failure so as to restore an item to operate within specified limits.

Rework: Return for completion of operations (complete to drawing). The article is to be reprocessed to conform to the original specifications or drawings.

Section: See Level of Assembly.

Similarity: Verification by: a procedure of comparing an item to a similar one that has been verified. Configuration, test data, application and environment should be evaluated. It should be determined that design differences are insignificant, environmental stress will not be greater in the new application, and that manufacturer and manufacturing methods are the same.

Single Point Failure: The failure of a single hardware element which would result in loss of mission objectives, hardware, or crew, as defined for the specific application or project for which a single point failure analysis is performed.

Spacecraft: See Level of Assembly.

Subassembly: See Level of Assembly.

Subsystem: See Level of Assembly.

Temperature Cycle: A transition from some initial temperature condition to temperature stabilization at one extreme and then to temperature stabilization at the opposite extreme, then returning to the initial temperature condition.

Temperature Stabilization: The condition that exists when the rate of change of temperatures has decreased to the point where the test item may be expected to remain within the specified test tolerance for the necessary duration or where further change is considered acceptable.

Thermal Balance Test: A test conducted to verify the adequacy of the thermal model, the adequacy of the thermal design, and the capability of the thermal control system to maintain thermal conditions within established mission limits.

Thermal-Vacuum Test: A test conducted to demonstrate the capability of the test item to operate satisfactorily in vacuum at temperatures based on those expected for the mission. The test, including the gradient shifts induced by cycling between temperature extremes, can also uncover latent defects in design, parts, and workmanship.

Torque Margin: Torque margin is equal to the torque ratio minus one.

Torque Ratio: Torque ratio is a measure of the degree to which the torque available to accomplish a mechanical function exceeds the torque required.

Total Mass Loss (TML): Total mass of material outgassed from a specimen that is maintained at a specified constant temperature and operating pressure for a specified time.

Unit: See Level of Assembly.

Validation: The process of evaluating software and hardware during, or at the end of, the software or hardware development process to determine whether it satisfies specified requirements.

Verification: The process of evaluating software and hardware to determine whether the products of a given development phase (or activity) satisfy the conditions imposed at the start of that phase (or activity).

Vibroacoustics: An environment induced by high-intensity acoustic noise associated with various segments of the flight profile; it manifests itself throughout the payload in the form of directly transmitted acoustic excitation and as structure-borne random vibration.

Workmanship Tests: Tests performed during the environmental verification program to verify adequate workmanship in the construction of a test item. It is often necessary to impose stresses beyond those predicted for the mission in order to uncover defects. Thus random vibration tests are conducted specifically to detect bad solder joints, loose or missing fasteners, improperly mounted parts, etc. Cycling between temperature extremes during thermal-vacuum testing and the presence of electromagnetic interference during EMC testing can also reveal the lack of proper construction and adequate workmanship.

Witness: A personal, on-the-scene observation of a performance assurance activity with the purpose of verifying compliance with project requirements (see Monitor).